MARINE MAMMAL MONITORING DURING UNIVERSITY OF ALASKA FAIRBANKS' MARINE GEOPHYSICAL SURVEY ACROSS THE ARCTIC OCEAN, AUGUST–SEPTEMBER 2005

Prepared by

LGL LIMITED
environmental research associates

22 Fisher St., POB 280, King City, Ont. L7B 1A6, Canada

for

University of Alaska Fairbanks, Geophysical Institute
903 Koyukuk Dr., P.O. Box 757320
Fairbanks, AK 99775

and

National Marine Fisheries Service, Office of Protected Resources
1315 East-West Hwy, Silver Spring, MD 20910-3282

LGL Report TA4122-3

January 2006

Marine Mammal Monitoring During University of Alaska Fairbanks' Marine Geophysical Survey across the Arctic Ocean, August–September 2005

by

Beth Haley [a] and Darren Ireland [a]

[a] **LGL Alaska Research Associates, Inc.**
1101 East 36th Ave., Suite B, Anchorage, AK 99518, U.S.A.

and

LGL Limited, environmental research associates
P.O. Box 280, 22 Fisher Street, King City, Ont. L7B 1A6, Canada

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LGL Report 4122-3

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Suggested format for citation:

Haley, B. and D. Ireland. 2006. Marine mammal monitoring during University of Alaska Fairbanks' marine geophysical survey across the Arctic Ocean, August–September 2005. LGL Rep. TA4122-3. Rep. from LGL Ltd., King City, Ont., for University of Alaska Fairbanks, Fairbanks, AK, and Nat. Mar. Fish. Serv., Silver Spring, MD. 80 p.

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LIST OF ACRONYMS AND ABBREVIATIONS

~	approximately
ADCP™	Acoustic Doppler Current Profiler
Bf	Beaufort Wind Force
BO	Biological Opinion
CFR	(U.S.) Code of Federal Regulations
CITES	Convention on International Trade in Endangered Species
cm	centimeter
CPA	Closest (Observed) Point of Approach
CTD	conductivity, temperature, depth
dB	decibels
EA	Environmental Assessment
ESA	(U.S.) Endangered Species Act
$f(0)$	sighting probability density at zero perpendicular distance from survey track; equivalently, 1/(effective strip width)
ft	feet
G. gun	variant of an airgun, manufactured by Sodera, a French company owned by Sercel
GIS	Geographic Information System
GMT	Greenwich Mean Time
$g(0)$	probability of seeing a group located directly on a survey line
h	hours
Hz	Hertz (cycles per second)
IHA	Incidental Harassment Authorization (under U.S. MMPA)
in^3	cubic inches
IUCN	International Union for the Conservation of Nature
kHz	kilohertz
km	kilometer
km^2	square kilometers
km/h	kilometers per hour
kt	knots
L-DEO	Lamont-Doherty Earth Observatory (of Columbia University)
μPa	micro Pascal
m	meters
MBB	Multibeam Bathymetric (sonar)
MCS	Multi-Channel Seismic
min	minutes
MMO	Marine Mammal Observer
MMPA	(U.S.) Marine Mammal Protection Act
n	sample size
n.mi.	nautical miles
NMFS	(U.S.) National Marine Fisheries Service
No.	number

NPD	Norwegian Petroleum Directorate
NSF	(U.S.) National Science Foundation
PD	Power down of the G. guns to half volume (in this study, from 2 × 250 in^3 to 2 × 125 in^3)
pk-pk	peak-to-peak
re	in reference to
rms	root-mean-square
s	seconds
SD	Shut Down of G. guns not associated with mitigation
s.d.	standard deviation
SZ	Shut Down of all the G. guns because of a marine mammal or sea turtle sighting near or within the safety radius
TTS	Temporary Threshold Shift
UAF	University of Alaska Fairbanks
UiB	University of Bergen
UNEP	United Nations Environmental Programme
USCG	United States Coast Guard
USCGC	United States Coast Guard cutter
"Useable"	Visual effort or sightings made under the following observation conditions: daylight periods within the study area, ***excluding*** periods 3 min to 2 h after airguns were turned off (post-seismic), poor visibility conditions (visibility <2 km), and periods with Beaufort Wind Force >5. Also excluded were periods with >60º of severe glare between 90º left and 90º right of the bow. Sightings of marine mammals hauled out on the ice were considered "useable" for analyses.

EXECUTIVE SUMMARY

Introduction

This document serves to meet reporting requirements specified in an Incidental Harassment Authorization (IHA) issued to the University of Alaska Fairbanks (UAF) by the National Marine Fisheries Service (NMFS) on 5 Aug. 2005. The IHA (Appendix A) authorized non-lethal takes of certain marine mammals incidental to a marine seismic survey across the Arctic Ocean. Behavioral disturbance to marine mammals is considered to be "take by harassment" under the provisions of the U.S. Marine Mammal Protection Act (MMPA). NMFS considers that marine mammals exposed to airgun sounds with received levels ≥160 dB re 1 µPa (rms) might be sufficiently disturbed to be "taken by harassment". "Taking" would also occur if marine mammals close to the seismic activity experienced a temporary or permanent reduction in their hearing sensitivity, or reacted behaviorally to the airgun sounds in a biologically significant manner.

It is not known whether seismic exploration sounds are strong enough to cause temporary or permanent hearing impairment in any marine mammals that occur close to the seismic source. Nonetheless, NMFS requires measures to minimize the possibility of any injurious effects (auditory or otherwise), and to document the extent and nature of any disturbance effects. In particular, NMFS requires that seismic programs conducted under IHAs include provisions to monitor for marine mammals, and to shut down or power down the airguns when mammals are detected within designated safety radii. In this project, a power down was a reduction of the operating airgun volume by half, whereas a shut down involved the complete cessation of firing by all airguns.

Seismic Program Described

The purpose of the seismic survey was to study the history of the ridges and basins of the Arctic Ocean. The seismic reflection and refraction data will assist in the analysis of the internal structure of the ridges and plateaus of the Amerasian basin and assist in the determination of the stratigraphy of intervening basins. The survey extended from northern Alaska to the North Pole and then south to Svalbard. Water depths within the seismic survey area were 223–4873 m. Twenty percent of the seismic survey (~449 km) was conducted in water 100–1000 m deep, but most (80%) of the survey (~1824 km) occurred in water deeper than 1000 m. None of the seismic survey was conducted in water less than 100 m deep. Most of the seismic survey was conducted far from any country's territorial waters. However, ~63 km of airgun operations occurred within 200 n.mi. (370 km) of the Alaska coast. Also, ~6 km of seismic operations occurred through ice within 200 n.mi. of Svalbard's coast, but no seismic data were collected there because of equipment malfunction.

The USCG cutter *Healy* departed Dutch Harbor, Alaska, on 5 Aug. 2005 and began seismic operations north of Alaska on 10 Aug. A Swedish icebreaker, the *Oden*, met the *Healy* near 84°N on 1 Sept. to facilitate breaking through the heavier pack ice between there and the North Pole, and then southward toward Svalbard. Personnel aboard the *Oden* were conducting their own oceanographic research. The two icebreakers traveled together until 23 Sept., when they were northeast of Svalbard near 82°N. The seismic study was concluded on 26 Sept. 2005, to the northwest of Svalbard. The *Healy* then sailed south and arrived in Tromsø, Norway, on 30 Sept.

This seismic survey was conducted using two Sodera 250 in^3 G. guns that were deployed from the *Healy*. The IHA issued by NMFS also authorized exposing marine mammals to sounds from a single

1200 in^3 Bolt airgun, but that was never employed in the survey. Initially, a streamer consisting of three 100-m sections and containing hydrophones was also towed behind the *Healy* to receive returning seismic signals. A length of the streamer broke off in the ice on 24 Aug. After that only two sections of streamer were deployed to reduce the risk of losing more equipment. In addition, sonobuoys were deployed from the *Healy* to relay airgun returns. The marine mammal observers also listened to the sonobuoy signals on a scheduled basis to detect marine mammal calls. A multibeam bathymetric sonar and a lower energy 3.5 kHz sub-bottom profiler were operated from the *Healy* throughout all or much of the survey.

Monitoring and Mitigation Description and Methods

Four marine mammal observers (MMOs), including three biologists and one Inupiat, were aboard the *Healy* throughout the period of operations for visual and acoustic monitoring. The primary purposes of the monitoring and mitigation effort were the following: ***(A)*** Document the occurrence, numbers and behaviors of marine mammals near the seismic source based primarily on visual observations and secondarily on listening for marine mammal calls. ***(B)*** Implement a power down or shut down of the G. guns when marine mammals were sighted near or within the designated sound radii. ***(C)*** Monitor for marine mammals before and during ramp-up periods.

At least one MMO watched for marine mammals at all times while G. guns operated during daylight periods. For most of the survey, this schedule spanned 24 h per day because darkness was not encountered until 23 Sept., near the end of the survey.

The MMOs used 7 x 50 binoculars, 25 x 150 Big-eye binoculars, and the naked eye to scan the surface of the water around the vessel for marine mammals. The distance from the observer to the sighting was estimated using reticles on the binoculars and angles from a clinometer. When a marine mammal was detected within or approaching the safety radius, the MMO(s) contacted the airgun operators to request a power down or shut down of the G. guns.

MMOs also monitored for marine mammal vocalizations during seismic operations by listening to the transmission from the sonobuoys during ~1/3rd of “visual” watch periods. The primary purpose of the acoustic monitoring was to identify the presence of marine mammals in the survey area. Acoustic detections were not to be used to implement mitigation measures, as the sonobuoys could not provide information on distances of mammals from the airguns. The sonobuoy was located at varying distances behind the vessel (depending on time since deployment and vessel speed), and the sounds received might have been from several kilometers away. Also, the sonobuoys are omnidirectional and unable to determine the locations of calling mammals. The MMO listened with noise-canceling headphones to sounds received from the sonobuoys. If a calling cetacean was detected, the MMO was to record the presence of the animal.

Primary mitigation procedures, as required by the IHA, included the following: ***(A)*** Ramp ups, consisting of an increase in the operating volume of the G. guns from half to full whenever the guns were started after periods without seismic operations. ***(B)*** Immediate power downs or shut downs of the G. guns whenever marine mammals were detected within or about to enter the applicable safety radius. The safety radii used during the survey were based on the distances within which the received levels of G. gun sounds were expected to diminish to 190 (for pinnipeds) or 180 (for cetaceans) dB re 1 µPa rms. Separate radii were used during operations in deep (>1000 m) water vs. intermediate-depth (100–1000 m) water. During operations with two G. guns, the safety radii for pinnipeds were 100 and 150 m for deep and intermediate water depths; the corresponding safety radii for cetaceans were 325 and 500 m, respectively.

Monitoring Results

The study area for the purposes of the marine mammal analyses was the actual seismic survey area, including the area traversed during the 2 h periods prior to the beginning and after the end of seismic operations. The transits from Dutch Harbor, Alaska, to the start of the study area north of Alaska, and from the end of the survey northwest of Svalbard to the port of Tromsø, Norway, traversed vastly different habitat from that encountered during the survey. It would not be appropriate to compare the animals and sighting rates encountered during these transits with those within the ice pack where the survey occurred.

The *Healy* traveled a total of 7381 km within the study area (Table ES.1). This included the ship track within the Polar Basin from 2 h before the first airgun operations until 2 h after the last airgun operations (see Fig. 1.1 in Chapter 1). The airguns operated along ~31% of that total ship track, and always during daylight. All of the seismic operations were conducted with the 2 G. guns. The actual number of kilometers traveled during seismic periods was lower than anticipated in the IHA application and EA (2273 vs. 4131 km). Ramp ups of the airguns occurred on 65 occasions. No ramp ups were conducted at night.

In total, 4768 km of visual observations and 739 km of acoustic monitoring were conducted (Table ES.1). MMOs were on visual watch during all ramp ups and all periods with airgun operations. Acoustic monitoring also occurred during portions of all seismic periods, i.e., for ~1/3rd of every hour of watch during seismic operations. All visual and acoustic monitoring effort occurred during daylight as there was no darkness at the high survey latitudes until 23 Sept. After 23 Sept., there was less than an hour of seismic operations, and that occurred during the daylight. No marine mammal calls were detected by listening to the sonobuoy signals.

Sighting data collected within the study area were acquired under greatly varying conditions. Ice conditions ranged between 10 and 100% coverage and the ice thickness varied between extremely thin to several meters thick. In addition, the *Oden* traveled with the *Healy* for 23 days. The *Oden*'s proximity and location relative to the *Healy* varied widely during that period. The effects of the variable ice conditions and the *Oden's* variable presence on the sightability of marine mammals were impossible to determine. Therefore, the sighting data from the Arctic Ocean survey were not used to estimate marine mammal density or the number of potentially disturbed marine mammals. Density data from previous marine mammal surveys in the study area, as assembled via a literature review, were used instead. Those previous results were summarized and used in the IHA application and EA prepared for this project.

Analyses of pinniped and cetacean behavior focused on sightings and survey effort in the study area during periods with "useable" survey conditions, which represented ~66% of the total visual effort (in hours; Table ES.1). "Useable" effort excluded periods 3 min to 2 h after airguns were turned off (post-seismic), periods with poor visibility (<2 km), and periods with Beaufort Wind Force >5. Also excluded were periods with >60° of severe glare between 90º left and right of the bow.

No cetaceans were observed by MMOs within the study area, either visually or through acoustic monitoring. Six groups of mysticetes (baleen whales), including 7 individuals, and five groups of odontocetes (toothed whales), including 17 individuals, were observed during transits outside of the study area.

Nineteen groups of polar bears (24 individuals) were sighted throughout the study area. No bears were observed in the water during seismic operations.

TABLE ES.1. Summary of Healy operations, observer and acoustic monitoring effort, and marine mammal sightings during the marine geophysical survey across the Arctic Ocean, 10 Aug. – 26 Sept. 2005. No cetaceans were observed within the study area. Two power downs and a single shut down occurred due to the presence of pinnipeds.

	Non-Seismic			Seismic			
	Useable[a]	**Other**	**Post Seismic**	**Useable[a]**	**Other**	**Total Useable[a]**	**Total**
Total Operations in h							
Healy	691	64	95	205	89	896	1144
Observer	230	63	76	205	89	435	664
Acoustic Monitoring	-	-	-	98	-	98	98
Total Operations in km							
Healy	4266	383	459	1597	676	5863	7381
Observer	1741	382	373	1597	676	3338	4768
Acoustic Monitoring	-	-	-	739	-	739	739
No. Pinniped Sightings In water (Indiv.)	15 (15)	-	1 (1)	41 (41)	5 (5)	56 (56)	62 (62)
No. Pinniped Sightings On Ice (Indiv.)	4 (4)	-	1 (1)	11 (11)	-	15 (15)	16 (16)
No. Polar Bear Sightings (Indiv.)	11 (12)	1 (3)	2 (2)	4 (6)	1 (1)	15 (18)	19 (24)
No. Power Downs / Shut Downs	-	-	-	2	1	2	3

[a] See *Acronyms and Abbreviations* for the definition of "useable" effort.

A total of 78 pinnipeds (in 78 groups) were observed within the study area, 62 in the water and 16 on ice (Table ES.1). Ringed seals are known to occur regularly in the deep Arctic waters of the Beaufort Sea and the great majority of identified seals were indeed ringed seals (35 of 42). The remaining seven seals identified to species by observers were bearded seals. An additional 36 "unidentified" seals were sighted within the study area. These animals were most likely ringed seals, given the ringed seal's relative abundance and distribution through the study area. Both of the power downs and the single shut down implemented during the study were a result of the presence of pinnipeds. Although three polar bear kills (seals) were observed during the study, no injured pinnipeds potentially associated with the seismic operations were sighted at any time. Two different polar bears were observed feeding on seals. Also, a seal carcass, evidently a polar bear kill that was partially eaten, was sighted during the survey.

Marine mammals that are out of the water are not exposed to significant sounds from airguns operating below the surface. Therefore, pinniped sightings are separated into two categories (in water and on ice) throughout this report. Neither shut downs nor power downs were requested for marine mammals that were out of the water.

In general, the relatively small numbers of sightings (n = 97) did not allow meaningful interpretation of sighting rates and behavior during seismic vs. non-seismic periods. However, the observed sighting rate trend was contradictory to trends during many other seismic surveys: during this Arctic

Ocean seismic survey, marine mammal sighting rates were nearly twice as high during seismic activities as during non-seismic periods. During more typical seismic surveys, the rate of sightings is usually lower when the airguns are operating than when they are silent, and average distances of the sighted mammals from the vessel are usually greater when the airguns are operating. In those cases, it is assumed that many species tend to avoid the approaching noise source, sometimes before the mammals are detected by observers. During the present study, seismic operations were conducted as often as possible in areas of open water (leads and polynyas) to avoid ice-induced damage to the equipment. Seals tended to concentrate in these areas of open water, where they can feed and avoid polar bears. The polar bears also tended to congregate in these areas, presumably because of the higher seal concentrations. This association of both seismic surveys and marine mammals with leads and polynyas accounted for the higher sighting rate during seismic surveys.

Number of Marine Mammals Present and Potentially Affected

During this project, the "sound level radii" called for by NMFS were, for pinnipeds, the best estimates of the 190-dB re 1 μPa (rms) radii for two G. guns with a total volume of 500 in^3. Those radii were estimated to be 100 m in water >1000 m deep, and 150 m in water 100–1000 m deep. The U.S. Fish and Wildlife Service, which has jurisdiction over polar bears (and walruses), agreed that the same safety radius would also be appropriate for polar bears. All 97 marine mammal sightings made within the study area were of seals and polar bears. Three power downs were requested on the three separate occasions, all in water 100–1000 m deep, when individual seals were sighted within the 190 dB safety radius (150 m) around the operating G. guns (Table ES.1). The first of these seals was seen diving well within the 150 m safety zone (~92 m from the guns), and was very likely exposed to airgun sounds with received levels ≥190 dB re 1 μPa (rms) before mitigation measures were implemented. The other two seals were observed diving 136 and 148 m from the noise source, where levels could exceed 190 dB only at a considerable depth below the surface. It is unlikely that those two seals were exposed to 190 dB sounds before the G. guns were powered down or fully shut down. However, implementation of a power down or shut down reduced the duration of exposure to strong G. gun sounds. Because all polar bears observed during seismic activities were on the ice, none are believed to have been exposed to strong sounds from the G. guns.

Any large cetaceans that might have been exposed to received sound levels ≥160 dB re 1 μPa (rms), and delphinids or pinnipeds exposed to received levels ≥170 dB re 1μPa, were assumed to have been potentially disturbed during the seismic study. As noted earlier, reliable estimates of marine mammal densities along the trackline could not be obtained in the circumstances of this cruise. Based on density estimates from earlier projects, a total of 3501 individual pinnipeds might have been exposed to G. gun sound with levels ≥160 dB, and 1121 might have been exposed to ≥170 dB around the operating airguns. The 170 dB radius is considered a more realistic disturbance criterion for pinnipeds. Although no cetaceans were sighted or heard during the seismic survey, it is possible that some were present close to the trackline but not seen. Based on the density estimates from other projects, a total of 129 individual cetaceans (bowhead whales, beluga whales, and narwhals) might have been exposed to ≥160 dB.

In summary, the maximum estimated numbers of seals (ringed seals, bearded seals and spotted seals) and cetaceans (bowheads, belugas, and narwhals) potentially affected by UAF's seismic survey were lower than the respective numbers authorized by NMFS (4811 and 511 authorized to be exposed to ≥160 dB). Also, the actual numbers seen near the operating airguns were much less than the estimates derived from density data acquired during other projects that were not fully representative of this one.

Given this, and the mitigation measures that were applied, the effects were very likely localized and transient, with no significant impact on either individual marine mammals or their populations. Given the far-offshore location of the survey work, there was also no potential for any effects on the availability of marine mammals for subsistence hunting in Alaska.

1. BACKGROUND AND INTRODUCTION

The University of Alaska Fairbanks (UAF) conducted a seismic study during a cruise across the Arctic Ocean from Alaska to Svalbard from 5 Aug. to 30 Sept. 2005 (Fig. 1.1). The seismic operations were conducted aboard the United States Coast Guard (USCG) cutter *Healy*, an icebreaker. The National Science Foundation (NSF), a U.S. Government agency, and the Norwegian Petroleum Directorate (NPD) provided the bulk of the funding for the seismic survey, which was an international collaborative effort. During the survey, the *Healy* rendezvoused with the Swedish icebreaker *Oden* near Alpha Ridge, on 1 Sept. (Fig. 1.1). The *Oden*, working on a separate project conducting an oceanographic section across the Arctic Ocean basin, coordinated its timing to meet the *Healy*. The *Oden* assisted the *Healy* with cutting a path through the ice past the North Pole and then on towards Svalbard, separating from the *Healy* on 23 Sept. Seismic operation occurred periodically from 10 Aug. through 26 Sept.

The purpose of the seismic study was to collect seismic reflection and refraction data that reveal the structure and stratigraphy of the upper crust of the Arctic Ocean. These data will assist in determining the history of ridges and plateaus that subdivide the Amerasian Basin in the Arctic Ocean (Fig. 1.1). The study employed an airgun cluster consisting of 2 G. guns with a total air discharge volume of 500 in^3 as the energy source. The geophysical investigation was under the direction of chief scientists Dr. Bernard Coakley of the University of Alaska Fairbanks, Dr. John Hopper of Texas A&M, and Dr. Yngve Kristoffersen of the University of Bergen. This seismic project was operated in conjunction with a sediment coring project intended to collect paleoenvironmental and paleoceanographic evidence that will reveal information about the recent history of the Arctic Ocean and its climate during the last ten thousand years.

Marine seismic surveys emit strong sounds into the water (Greene and Richardson 1988; Tolstoy et al. 2004a,b), and have the potential to affect marine mammals, given the known auditory and behavioral sensitivity of many such species to underwater sounds (Richardson et al. 1995; Gordon et al. 2004). The effects could consist of behavioral or distributional changes, and perhaps (for animals close to the sound source) temporary or permanent reduction in hearing sensitivity. Either behavioral/distributional effects or (if they occur) auditory effects could constitute “taking” under the provisions of the U.S. Marine Mammal Protection Act (MMPA) and the U.S. Endangered Species Act (ESA), at least if the effects are considered to be “biologically significant”.

Numerous species of cetaceans and pinnipeds inhabit parts of the Arctic Ocean. Several species listed as “Endangered” under the ESA occur in portions of the survey area, including the sperm whale (*Physeter macrocephalus*), bowhead whale (*Balaena mysticetus*), humpback whale (*Megaptera novaeangliae*), fin whale (*Balaenoptera physalus*), and blue whale (*B. musculus*). Other species of concern (birds) that might occur in the area close to Barrow are the spectacled (*Somateria fischeri*) and Steller’s (*Polysticta stelleri*) eiders that are listed as “Threatened” under the ESA. Of the two species, spectacled eiders have been documented farther offshore (40 km) in the Barrow area. It was considered highly unlikely that either eider species would be encountered during the initial portion of the seismic survey that began ~340 km offshore of Barrow. Steller’s eiders can range north into Svalbard during the winter, but their occurrence is considered casual or accidental there, and it was also considered highly unlikely that any would be encountered near Svalbard during the proposed survey. Spectacled eiders range to northern Norway in some winters but were not expected to occur in the survey area during the latter portion of the survey. Another species of special concern that is very unlikely to occur in the study area is the leatherback turtle (*Dermochelys coriacea*), which is listed as “Endangered” under the ESA. Leatherback turtles have been encountered in the Norwegian Sea but they do not breed in Norwegian waters.

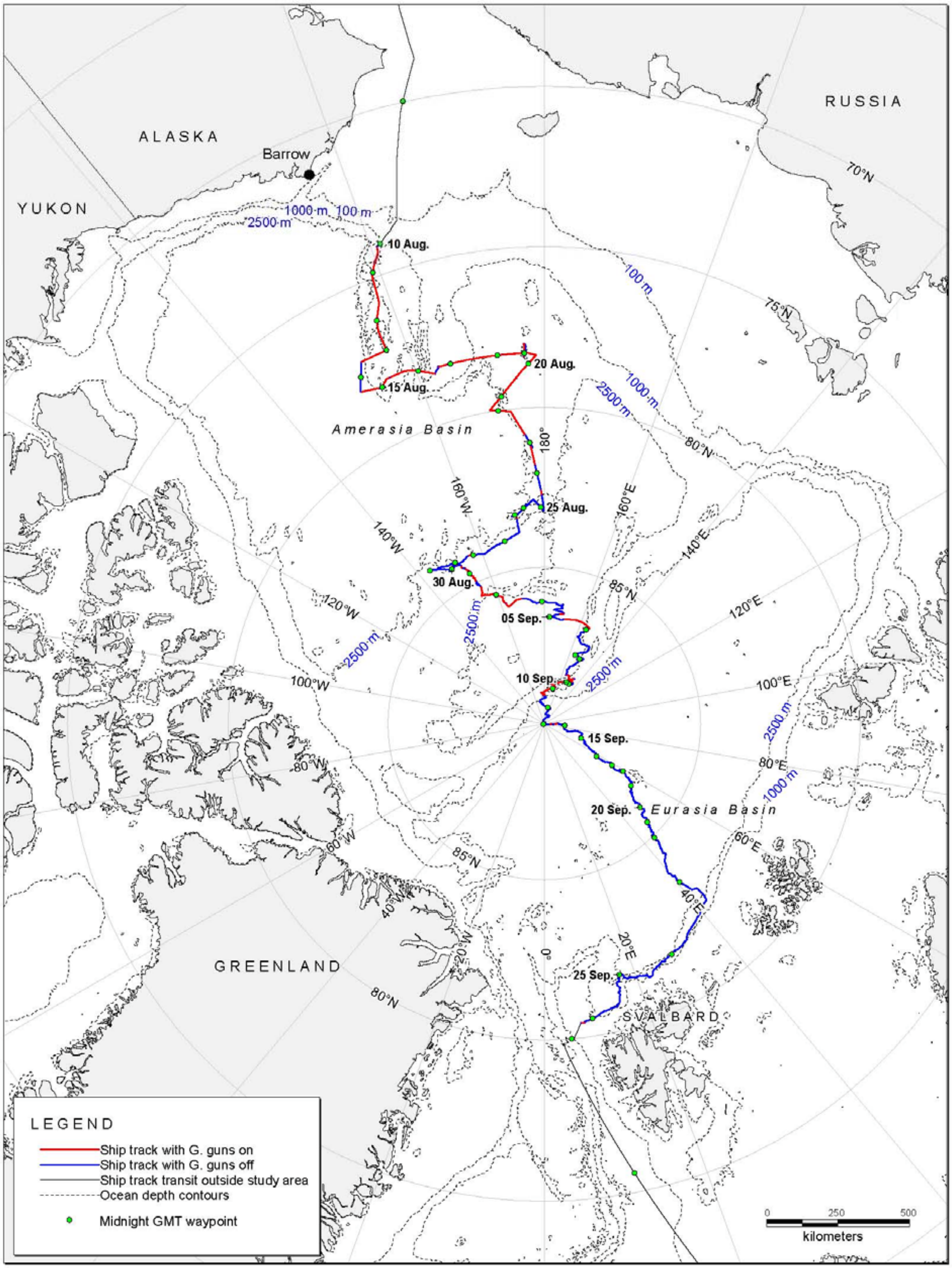

FIGURE 1.1. The Healy's trackline across the Arctic Ocean from northwest of Barrow, Alaska, to northwest of Svalbard, showing (in red) the parts of the track where seismic operations occurred.

On 30 March 2005, UAF requested that the National Marine Fisheries Service (NMFS) issue an Incidental Harassment Authorization (IHA) to authorize non-lethal "takes" of marine mammals incidental to the seismic operations across the Arctic Ocean (LGL Ltd. 2005a). The IHA was requested pursuant to Section 101(a)(5)(D) of the MMPA. An Environmental Assessment (EA) was also written to evaluate the potential impacts of the marine seismic survey across the Arctic Ocean (LGL Ltd. 2005b). That EA was adopted by NSF. The IHA was issued by NMFS on 5 Aug. 2005 (Appendix A). The IHA authorized "potential take by harassment" of various cetaceans and pinnipeds during the marine geophysical cruise described in this report.

The project was also conducted under the provisions of Licence 438/2005 issued by the Norwegian Petroleum Directorate to NSF for purposes of scientific research.

This document serves to meet reporting requirements specified in the IHA. The primary purposes of this report are to describe the seismic survey across the Arctic Ocean, to describe the associated marine mammal monitoring and mitigation programs and their results, and to estimate the numbers of marine mammals potentially affected by the project.

Incidental Harassment Authorization

IHAs issued to seismic operators include provisions to minimize the possibility that marine mammals close to the seismic source might be exposed to levels of sound high enough to cause hearing damage or other injuries. During this project, sounds were generated by the airguns (G. guns) used during the seismic study, a multibeam bathymetric (MBB) sonar, two sub-bottom profilers, an acoustic Doppler current profiler (ADCP™), and general vessel operations. No serious injuries or deaths of marine mammals were anticipated from the seismic survey, given the nature of the operations and the mitigation measures that were implemented, and no injuries or deaths were attributed to the seismic operations. Nonetheless, the seismic survey operations described in Chapter 2 had the potential to "take" marine mammals by harassment. Behavioral disturbance to marine mammals is considered to be "take by harassment" under the provisions of the MMPA. Appendix C provides further background on the issuance of IHAs relative to seismic operations and "take".

Under current NMFS guidelines (e.g., NMFS 2005a), "safety radii" for marine mammals around airgun arrays are customarily defined as the distances within which the received pulse levels are ≥180 dB re 1 μPa (rms)[1] for cetaceans and ≥190 dB re 1 μPa (rms) for pinnipeds. Those safety radii are based on an assumption that seismic pulses received at lower received levels will not injure these mammals or impair their hearing abilities, but that higher received levels *might* have some such effects. The mitigation measures required by IHAs are, in large part, designed to avoid or minimize the numbers of cetaceans and pinnipeds exposed to sound levels exceeding 180 and 190 dB (rms), respectively.

Disturbance to marine mammals could occur at distances beyond the safety (shut down) radii if the mammals were exposed to moderately strong pulsed sounds generated by the airguns or perhaps by sonar (Richardson et al. 1995). NMFS assumes that marine mammals exposed to airgun sounds with received levels ≥160 dB re 1 μPa (rms) are likely to be disturbed appreciably. That assumption is based mainly on

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[1] "rms" means "root mean square", and represents a form of average across the duration of the sound pulse as received by the animal. Received levels of airgun pulses measured on an "rms" basis are generally 10–12 dB lower than those measured on the "zero-to-peak" basis, and 16–18 dB lower than those measured on a "peak-to-peak" basis (Greene 1997; McCauley et al. 1998, 2000). The latter two measures are the ones commonly used by geophysicists. Unless otherwise noted, all airgun pulse levels quoted in this report are rms levels.

data concerning behavioral responses of baleen whales, as summarized by Richardson et al. (1995) and Gordon et al. (2004). Dolphins and pinnipeds are generally less responsive than baleen whales (e.g., Stone 2003; Gordon et al. 2004), and 170 dB (rms) may be a more appropriate criterion of potential behavioral disturbance for those groups (LGL Ltd. 2005a,b). In general, disturbance effects are expected to depend on the species of marine mammal, the activity of the animal at the time of disturbance, distance from the sound source, the received level of the sound and the associated water depth. Some individuals may exhibit behavioral responses at received levels somewhat below the nominal 160 or 170 dB (rms) criteria, but others may tolerate levels somewhat above 160 or 170 dB without reacting in any substantial manner.

A notice regarding the proposed issuance of an IHA for the survey across the Arctic Ocean was published by NMFS in the *Federal Register* on 10 May 2005 and public comments were invited (NMFS 2005a). On 5 Aug. 2005, UAF received the IHA that had been requested for the Arctic Ocean project. On 15 Aug. 2005, NMFS published a second notice in the *Federal Register* to announce the issuance of the IHA (NMFS 2005b). The second notice responded to four comments received by NMFS during the 30-day public comment period. A copy of the IHA is included in this report as Appendix A.

The IHA was granted to UAF on the assumptions that

- the numbers of marine mammals potentially harassed (as defined by NMFS criteria) during seismic operations would be "small",
- the effects of such harassment on marine mammal populations would be negligible,
- no marine mammals would be seriously injured or killed,
- there would be no unmitigated adverse effects on the availability of marine mammals for subsistence hunting in Alaska, and
- the agreed upon monitoring and mitigation measures would be implemented.

The IHA issued for the Arctic Ocean seismic survey did not authorize harassment "takes" of four ESA-listed species (blue, fin, sei, and sperm whales) for which UAF had requested such authorization. NSF had requested a formal consultation with NMFS under Section 7 of the ESA regarding potential interactions with ESA-listed species. In the case of these four ESA-listed cetacean species, NMFS did not anticipate adverse effects. Therefore, NMFS did not address those species in an Incidental Take Statement, and did not grant incidental take authorization. However, NMFS requested that the same mitigation, monitoring, and reporting measures required for other marine mammals be implemented for any encounters with the four ESA-listed species excluded from the IHA. In addition, in the unlikely event that there were any sightings of blue, fin, sei or sperm whale, NMFS also asked for prompt notification. In actuality, no blue, fin, sei, or sperm whales were observed during the cruise.

The polar bear (*Ursus maritimus*) and Pacific walrus (*Odobenus rosmarus*) are managed by the U.S. Fish and Wildlife Service (USFWS), unlike other arctic marine mammals (which are managed by NMFS). However, the USFWS has no mechanism in place to issue an IHA. NSF conducted an informal consultation with the USFWS Office of Marine Mammal Management, Anchorage, regarding potential interactions with polar bears and Pacific walruses. USFWS wrote that the mitigation measures described in the IHA application for this survey would be appropriate for polar bears and Pacific walruses (Appendix B). It was agreed that the 180 dB radii would be applied as safety radii for Pacific walruses and the 190 dB radii for polar bears.

Mitigation and Monitoring Objectives

The objectives of the mitigation and monitoring program were described in detail in UAF's IHA application (LGL Ltd. 2005a) and in the IHA issued by NMFS to UAF (Appendix A). Explanatory material about the monitoring and mitigation requirements was published by NMFS in the *Federal Register* (NMFS 2005a,b).

The main purpose of the mitigation program was to avoid or minimize potential effects of UAF's seismic survey on marine mammals. This required that shipboard personnel detect marine mammals within or about to enter the safety radii, and in such cases initiate an immediate power down (or shut down if necessary) of the airguns. A power down involves reducing the source level of the operating airguns, in this case by reducing the air volume. A shut down involves temporarily terminating the operation of all airguns. An additional mitigation objective was to detect marine mammals within or near the safety radii prior to starting the airguns, or during ramp up toward full power. In these cases, the start of airguns was to be delayed or ramp up discontinued until the safety radius was free of marine mammals (see Appendix A and Chapter 3).

The primary objectives of the monitoring program were as follows:

1. provide real-time sighting data needed to implement the mitigation requirements;
2. estimate the numbers of marine mammals potentially exposed to strong seismic pulses;
3. determine the reactions (if any) of potentially exposed marine mammals; and
4. monitor sonobuoy transmissions for marine mammal vocalizations to document the presence of calling marine mammals.

Specific mitigation and monitoring objectives identified in the IHA are described in Appendix A. Mitigation and monitoring measures that were implemented during the trans-Arctic Ocean cruise are described in detail in Chapter 3.

Report Organization

The primary purpose of this report is to describe the 2005 Arctic Ocean seismic survey including the associated monitoring and mitigation programs, and to present results as required by the IHA (see Appendix A). This report includes four chapters:

1. background and introduction (this chapter);
2. description of the seismic study;
3. description of the marine mammal monitoring and mitigation requirements and methods, including safety radii;
4. results of the marine mammal monitoring program, including estimated numbers of marine mammals potentially "taken by harassment".

Those chapters are followed by Acknowledgements and Literature Cited sections.

In addition, there are nine Appendices. Details of procedures that are more-or-less consistent across recent NSF-sponsored seismic surveys where marine mammal monitoring and mitigation measures were in place are provided in the Appendices and are only summarized in the main body of this report. The Appendices include

A. a copy of the IHA issued to UAF for this study;

B. a copy of the letter of informal consultation issued by USFWS for this study

C. background on development and implementation of safety radii;

D. characteristics of the *Healy*, its airguns and its sonars;

E. details on visual and acoustic monitoring, mitigation, and data analysis methods;

F. conservation status and densities of marine mammals in the project region;

G. monitoring effort and list of marine mammals seen or heard during this cruise;

H. marine mammal sightings with power downs and shut downs during the Arctic Ocean cruise;

I. marine mammal density estimates for the Arctic Ocean project.

2. ARCTIC OCEAN SEISMIC SURVEY DESCRIBED

Procedures used to obtain seismic data during the trans-Arctic Ocean study were generally similar to those used during previous seismic surveys, e.g., Lamont-Doherty Earth Observatory's (L-DEO) study off the coast of Newfoundland in the North Atlantic (Holbrook et al. 2003) and L-DEO's study in the SE Caribbean (Smultea et al. 2004). However, some specialized procedures were necessary to deal with the ice—most notably the use of an icebreaker as the source vessel, with assistance from another icebreaker at the most northerly latitudes. The Arctic Ocean survey used conventional seismic reflection and refraction techniques to characterize the earth's crust, including two 250 in^3 G. guns (airguns) as the energy source, and a towed hydrophone streamer along with sonobuoys as the receiver systems. Initially, three 100-m sections of streamer were deployed (300 m of streamer). After a section was lost to ice on 24 Aug., only two 100-m sections were used. In addition, sonars were used to map the bathymetry and sub-bottom conditions to obtain data needed for the geophysical studies.

The following sections briefly describe the seismic survey, the equipment used for the study, and its mode of operation, insofar as necessary to satisfy the reporting requirements of the IHA (Appendix A). More detailed information on the *Healy* and the equipment is provided in Appendix D.

Operating Areas, Dates, and Navigation

The track of the Arctic Ocean project extended from Alaska to the North Pole and then south to Svalbard. More specifically, seismic operations occurred from 74.1ºN north to 90ºN, mainly between 145º and 180ºW, and then south to 80.5 ºN, mainly between 6ºE and 70ºE (Fig. 1.1). Water depth along the seismic survey ranged from 223 to 4873 m. Most of the seismic survey was conducted far from any country's territorial waters. However, ~63 km of the seismic operations were conducted within 200 n.mi. (370 km) of the coast of Alaska. Also, ~6 km of airgun operations occurred through ice-covered waters within 200 n.mi. of Svalbard, but no seismic data were collected there because of equipment malfunction. The *Healy* departed Dutch Harbor, Alaska, on 5 Aug. 2005 and arrived in the study area ~340 km northwest of Barrow on 10 Aug, when seismic operations began. Thereafter, seismic operations occurred intermittently over ~33 days until the last airgun operations ceased on 26 Sept. 2005. There was 24-hour daylight until 23 Sept., and no seismic operations were conducted in darkness. The *Healy* arrived in Tromsø, Norway, on 30 Sept. 2005. A chronology of the study is presented in Table 2.1. A summary of the total distances traveled by the *Healy* during the survey, distinguishing periods with and without seismic operations, is presented in Table ES.1.

Periodically throughout the Arctic Ocean survey, seismic activities were suspended for coring operations. This occurred at 22 locations. The coring operations constituted a separate project, also funded with an NSF grant, that were performed in conjunction with the seismic study from the *Healy*. Depending on water depth and the number of cores to be collected, the *Healy* was at each coring site between 0.5 and 9.5 hours. Also, three conductivity, temperature and depth (CTD) profiles were collected from the *Healy* during the survey, in conjunction with the coring project. Two stops that lasted ~1 and 3 h were made specifically to obtain CTD data.

Throughout the survey, position, speed, and water depth of the *Healy* were logged digitally every ~60 s. In addition, the position of the *Healy*, water depth, and information on the airgun array were logged for every airgun shot while the *Healy* was on a seismic line and collecting geophysical data. The geophysics crew kept an electronic log of events, as did the marine mammal observers (MMOs) while on duty. The MMOs also recorded the number and volume of airguns that were firing when the *Healy* was offline (e.g., prior to shooting at full volume) or was online but not recording data (e.g., during airgun or computer problems).

TABLE 2.1. Chronology in Greenwich Mean Time (GMT) of events during the Aug.– Sept. 2005 Arctic Ocean seismic survey.

Date (2005)	Time (GMT)	Event Description
05 Aug	18:00	*Healy* departed Dutch Harbor and began transit to survey area.
06 Aug		Transit to survey area.
07 Aug		Transit to survey area.
08 Aug		Transit to survey area.
09 Aug	17:07-17:21	Coring Station 1: HLY0503-01MC[a]
10 Aug	01:18 -11:16	Seismic operations (Lines 1 and 2); begin transit to Coring Station 2.
10 Aug	14:03-16:10	Coring Station 2: HLY0503-02JPC[b]; HLY0503-02MC Flight reconnaissance for ice research locations.
10 Aug	17:06	Recommence seismic activities (Line 3).
11 Aug		Seismic operations continue.
12 Aug	15:32	End of seismic operations (Line 6); begin transit to Coring Station 3.
12 Aug	17:40-19:51	Coring Station 3: HLY0503-03MC; HLY0503-03JPC. Boat operations for ice research during coring activities
13 Aug	01:49-18:03	Seismic operations (Lines 7-10); begin transit to Coring Station 4
14 Aug	00:05-00:31	Coring Station 4: HLY0503-04JPC; begin transit to next waypoint for seismic operations
14 Aug	11:26	Started seismic operations (Line 11).
15 Aug		Seismic operations continue.
16 Aug	08:43	End of seismic operations (Line 14); begin transit to Coring Station 5
16 Aug	09:46-11:53	Coring Station 5: HLY0503-05JPC; HLY0503-05MC.
16 Aug	17:10	Started seismic operations (Line 15).
17 Aug		Seismic operations continue.
18 Aug	15:13	End of seismic operations (line 18); heading to Coring Station 6
18 Aug	~14:48- 17:28	Coring Station 6: HLY0503-06JPC; HLY0503-06MC Flight operations for ice research during coring activities. Sonobuoy deployed by helicopter
18-19 Aug	20:08-01:21	Seismic operations (Line 19); begin transit to Coring Station 7.
19 Aug	10:30-11:12	Coring Station 7: HLY0503-07JPC.
19-20 Aug	13:46-20:32	Seismic operations (Lines 20-22); begin transit to Coring Station 8.
20-21 Aug	23:57-05:24	Coring Station 8: HLY0503-08JPC; transit to Coring Station 9.
21 Aug	08:26-10:05	Coring Station 9: HLY0503-09JPC. Ice survey.
21-22 Aug	11:34-17:16	Seismic operations (Lines 23-25).
23Aug	05:16-08:50	Coring Station 10: HLY0503-10JPC; HLY0503-10MC. Helicopter and boat operations for ice research.
23-24Aug	09:49-11:48	Seismic operations (Line 26-28); begin transit to Coring Station 11.
25 Aug	11:32-17:58	Helicopter operations and ice research at Coring Station 11. Installation of Web Cam PMEL- NOAA on Ice-Jamstec Drilling.
25 Aug	14:26-23:50	Coring Station 11: HLY0503-11CTD; HLY0503-11MC; HLY0503-11JPC.
26 Aug	17:04-20:02	Coring Station 12: HLY0503-12JPC; HLY0503-12MC.
26 Aug	22:10-00:45	Ice Liberty.
27 Aug	03:01	Attempts to start seismic operations failed due to thick ice; will wait for *Oden's* assistance to recommence seismic; begin transit to Coring Station 13
28 Aug	16:09-18:55	Coring Station 13: HLY0503-13JPC; HLY0503-13MC; begin transit to Coring Station 14.
29 Aug	00:20-02:17	Seismic operations (Line 30); begin transit to Coring Station 14

TABLE 2.1 (continued).

Date (2005)	Time (GMT)	Event Description
29 Aug	06:42-07:07	Dirty ice collection.
29-30 Aug	21:38-01:06	Coring Station 14: HLY0503-14JPC; HLY0503-14MC; Ice Survey. Begin transit to Coring Station 15.
30 Aug	02:45-03:54	Dirty ice collection.
30-31 Aug	21:09-01:02	Coring Station 15: HLY0503-15JPC; HLY0503-15MC; Ice Survey Begin transit to Coring Station 16.
31 Aug	16:24- 20:16	Coring Station 16: HLY0503-16JPC; HLY0503-16MC. Ice Survey
01 Sept	15:15	Meet with *Oden.*
01-02 Sept	18:45-04:43	Seismic operations (Lines 31 and 32); transit to Coring Station 17.
02 Sept	08:32-11:27	Coring Station 17: HLY0503-17JPC; HLY0503-17MC. Ice Survey
02 Sept	14:02	Seismic operations start (Line 33) after 2 hours of problems with streamer and guns.
03 Sept	18:39	Seismic operations end (Line 35), transiting north.
04 Sept	14:39-16:19	Seismic operations (Line 36).
05 Sept	09:11	Seismic operations begin (Line 37).
06 Sep	00:29	Seismic operations (Line 38) stopped due to heavy ice conditions. Transit north.
06 Sep	22:55-23:55	CTD Station 18: HLY0503-18ACTD. Ice survey.
07 Sep	4:32-07:13	Stopped for dirty ice collection; resume transit.
07 Sep	17:29-23:17	Helicopter operations required to find leads; resume transit.
08 Sep	12:33	Started seismic operations (Line 39)
09 Sep	11:35	Seismic operations stopped (Line 40); begin transit to Coring Station 18
09 Sep	12:25-16:44	Coring Station 18: HLY0503-18JPC; HLY0503-18MC. Ice Survey.
09-10 Sep	21:42-07:02	Seismic operations (Line 41); begin transit to Coring Station 19
10 Sep	8:42-10:51	Coring Station 19: HLY0503-19JPC; HLY0503-19MC. Ice Survey.
10 Sep	12:13-15:00	Seismic operations (Line 42); begin transit to Coring Station 20.
10 Sep	16:45-20:59	Coring Station 20: HLY0503-20JPC; HLY0503-20MC. Ice Survey
10-11 Sep	21:56-11:13	Seismic operations (Lines 43 and 44).
12 Sep	6:30-15:32	Ice liberty at North Pole.
13 Sep	6:44-11:15	Seismic operations (Lines 45 and 46). Seismic operations suspended until further notice due to ice conditions
14 Sep	17:29-20:43	CTD Station 21: HLY0503-21CTD Ice Survey.
15 Sep		Transit south
15 Sep	15:41-22:00	*Oden* CTD Station 47. Healy Ice Survey
16 Sep		Transit south
17 Sep	00:04-07:00	*Oden* CTD Station 50. Healy Ice Survey
17 Sep		Transit South
18 Sep	14:23-17:46	Coring Station 21: HLY0503-21JPC; HLY0503-21MC. Ice Survey

TABLE 2.1 (continued).

Date (2005)	Time (GMT)	Event Description
18 Sep		Transit South
19 Sep		Transit South
20 Sep	01:39-03:00	*Oden* CTD Station 51 Healy Ice Survey
20 Sep		Transit Southeast
21 Sep		Transit Southeast
22 Sep		Transit Southeast
23 Sep		Transit Southwest
23 Sep	13:00-15:00	Farewell to *Oden*
24 Sep		Transit Southwest
25 Sep		Transit Southwest
26 Sep	06:03- 09:00	Coring Station 22: HLY0503-22JPC; HLY0503-22MC. Ice Survey. Transit to next waypoint for Seismic Operations
26 Sep		Transit West along Sea Ice Edge
26 Sep	10:20	Seismic Operations started (Line 47).
26 Sep	11:05	A section of streamer lost, seismic suspended due to poor data acquisition
26 Sep		Transit West along Sea Ice Edge
27 Sep		Transit South to Tromsø
28 Sep		Transit South to Tromsø
29 Sep		Transit South to Tromsø
30 Sep	10:00	Healy docked in Tromsø, Norway.

[a]MC = multicore
[b]JPC = jumbo piston core

Airgun Characteristics

The University of Bergen's portable Multi-Channel Seismic (MCS) system was installed on the *Healy* for this cruise. This system included two Sodera 250 in^3 G. guns and a streamer up to 300 m long containing hydrophones. The *Healy* towed this system along a more or less predetermined survey track, adapted as necessary to deal with heavy ice conditions (Fig. 1.1). In addition to use of the streamer, sonobuoys of two types (AN/SSQ-57SPC and unspecified U.S. Navy surplus sonobuoys) were deployed at ~4 h intervals during seismic operations as an additional way to receive the reflected signals from the G. guns. The 2 G. gun cluster had a total discharge volume of 500 in^3. The energy source was towed as close to the stern as possible (~5 m behind) to minimize ice interference.

Compressed air supplied by compressors aboard the source vessel powered the airguns. Seismic pulses were emitted at intervals of ~20 s while the *Healy* traveled at an average speed of ~7.4 km/h (4 kt). The 20-s spacing corresponded to a shot interval of ~41 m. The G. gun configuration was towed below a depressor bird at a depth of 6 to 20 m depending on ice conditions; the preferred depth was 8–10 m, but the actual depth was usually 6 m. The two airguns were towed 1 m apart on the cross-track axis, separated by a spreader bar. The characteristics of the G. gun configuration used during the study are summarized in Table 2.2.

For the two G. gun source, the highest sound level measurable at any location in the water near the source would be slightly less than the nominal source level because the actual source is a distributed

TABLE 2.2. Specifications of the airguns used during UAF's Arctic Ocean seismic survey, 10 Aug.–26 Sept. 2005.

2 G. Gun Specifications	
Energy source	Two G. guns of 250 in^3 each, firing every 20 s 0-pk is 6.5 bar-m (236 dB re 1 μPa-m); pk-pk is 11.7 bar-m (241 dB) [a,b]
Towing depth of energy source	6.0 m
Total air discharge volume	500 in^3 (2 x 250 in^3)
Dominant frequency components	0–150 Hz

[a] For source at 5 m depth.

[b] Source level estimates are based on a filter bandwidth of ~0–250 Hz.

source rather than a point source. However, the two G. guns were only 1 m apart, so the non-point-source effect would be slight. Actual sound levels experienced by any organism more than 1 m from the G. gun source were lower than the source level.

Other Types of Seismic Operations

During the trans-Arctic Ocean cruise, airguns operated during certain other periods besides those in which seismic data were being recorded. Airguns were operated during ramp ups, power downs, line changes, periods of equipment repair, and testing of the airguns. Ramp ups were required by the IHA (see Chapter 3 and Appendix A). Ramp ups involved an increase in the volume of compressed air being released by the guns firing; volume was increased from half to full after 5 min. Ramp ups occurred when operations with the 2 G. guns commenced after a period without airgun operations. Ramp ups of the airguns occurred on 65 occasions during the seismic study: each involved a start up from no airguns operating.

Alternative seismic sources were considered for use but in fact were not operated during the cruise. UAF's IHA application described plans to use a single 1200 in^3 Bolt airgun in place of the two G. guns along parts of the cruise track. The 1200 in^3 source was not used. Also, the possibility of testing a lower energy source (a sparker) while at a coring station had been discussed with and approved by NMFS, but the unit was never tested.

Multibeam Bathymetric Sonar and Echosounders

Along with the airgun operations, four additional acoustic systems operated during the cruise. A 12-kHz SeaBeam multibeam bathymetric (MBB) sonar and a 3.5-kHz sub-bottom profiler operated throughout most of the cruise. These systems mapped the bathymetry and sub-bottom conditions, as necessary to meet the geophysical science objectives. During seismic operations, these sources typically operated simultaneously with the G. guns. Another sub-bottom profiler (ODEC Bathy 200) was used infrequently as back-up. A depth-sounding sonar, in this case an Acoustic Doppler Current Profiler, was used occasionally for safety purposes when the *Healy* was operating in shallow areas. Depth-sounders are employed routinely by sea-going vessels to monitor water depths. The various sonars are described in further detail in Appendix D. The pinger mentioned in the IHA Application was not used.

3. MONITORING AND MITIGATION METHODS

This chapter describes the marine mammal monitoring and mitigation measures implemented for UAF's Arctic Ocean seismic study, addressing the requirements specified in the IHA (Appendix A). The section begins with a brief summary of the monitoring tasks relevant to mitigation for marine mammals. The acoustic measurements and modeling results used to identify the safety radii for marine mammals are then described. A summary of the mitigation measures required by NMFS is then presented. The section ends with a description of the monitoring methods implemented for this cruise from aboard the *Healy*, and a description of data analysis methods.

Monitoring Tasks

The main purposes of the vessel-based monitoring program were to ensure that the provisions of the IHA issued to UAF by NMFS were satisfied, effects on marine mammals were minimized, and residual effects on animals were documented. The objectives of the monitoring program were listed in Chapter 1, *Mitigation and Monitoring Objectives*. Tasks specific to monitoring are listed below (also see Appendix A):

- Provide qualified MMOs for the *Healy* source vessel throughout the Arctic Ocean seismic survey.
- Visually monitor the occurrence and behavior of marine mammals near the G. guns when the airguns were operating and during a sample of the times when they were not.
- Record (insofar as possible) the effects of the airgun operations and the resulting sounds on marine mammals.
- Acoustically monitor the sonobuoy signals at intervals in order to detect calling marine mammals, and notify visual observers of the presence of marine mammals that are heard.
- Use the visual monitoring data as a basis for implementing the required mitigation measures.
- Estimate the number of marine mammals potentially exposed to strong G. gun sounds.

Safety and Potential Disturbance Radii

Under current NMFS guidelines (e.g., NMFS 2000), "safety radii" for marine mammals around airgun arrays are customarily defined as the distances within which received pulse levels are ≥180 dB re 1 μPa (rms) for cetaceans and ≥190 dB re 1 μPa (rms) for pinnipeds. These safety criteria are based on an assumption that seismic pulses received at lower received levels will not injure these animals or impair their hearing abilities, but that higher received levels *might* have some such effects. Marine mammals exposed to ≥160 dB (rms) are assumed by NMFS to be potentially subject to behavioral disturbance. However, for certain groups (dolphins, pinnipeds), available data indicate that disturbance is unlikely to occur unless received levels are higher, perhaps ≥170 dB rms for an average animal (see Chapter 1).

Radii within which received levels were expected to diminish to the various relevant values (i.e., 190, 180, 170 and 160 dB re 1 μPa rms) were estimated by L-DEO (Table 3.1). This was done based on a combination of acoustic modeling, as summarized in LGL Ltd. (2005a,b) and in Appendix C, along with empirical measurements of sounds from several airgun configurations (Tolstoy et al. 2004a,b). The acoustic modeling procedure did not allow for bottom reflections. Thus, it was directly applicable to close ranges and, for deep water, somewhat longer ranges, but not to ranges where received levels would be significantly affected by bottom reflections. The results from the empirical study were also limited in

TABLE 3.1. Estimated distances to which sound levels ≥190, 180, 170 and 160 dB re 1 μPa (rms) might be received from the G. guns during the Arctic Ocean seismic survey, Aug.-Sept. 2005. Distance estimates are given for operations in intermediate (100–1000 m) and deep (>1000 m) water, which are the depth strata where seismic operations occurred during this cruise. See Appendix C regarding derivation of these estimates. Safety radii implemented during the study are shown in **bold**.

Volume of Seismic Source (2 G.guns)	Water depth	Estimated Distances at Received Levels (m)			
		190 dB	180 dB	170 dB	160 dB
2 x 250 in^3	>1000	**100**	**325**	1050	3300
	100—1000 m	**150**	**500**	1600	5000
1 x 250 in^3 *	>1000	**17**	**52**	160	500
	100—1000 m	**26**	**78**	240	750

* With two GI-guns each operating at half volume (2 x 125 in^3), as occurred in this project during "ramp ups" and "power downs", the estimated distances would be less than for 2 x 250 in^3 but more than for 1 x 250 in^3.

various ways. However, the empirical data did show that (as expected) water depth can affect the distance at which received sound levels would exceed any specific level such as 180 or 170 dB re 1 μPa (rms). Therefore, three strata of water depth have been recognized during recent NSF-sponsored seismic cruises: deep (>1000 m), intermediate (100–1000 m), and shallow (<100 m), with associated differences in 160–190 dB radii (see Smultea et al. 2004, 2005; Holst et al. 2005a,b; MacLean and Koski 2005). The Arctic Ocean survey operations were conducted in water >100 m deep, so only intermediate and deep water radii were relevant.

Airguns operating underwater do not produce strong sounds in air. Accordingly, no shut downs or power downs were implemented for marine mammals on ice. (In any case, none of the sightings of marine mammals on the ice were within the then-appropriate underwater safety radius.)

Mitigation Measures as Implemented

The primary mitigation measures that were implemented during the Arctic Ocean cruise included ramp up, power down, and shut down of the G. guns. These measures are standard procedures during seismic cruises and are described in detail in Appendix E. Mitigation also included those measures specifically identified in the IHA (Appendix A) as indicated below.

Standard Mitigation Measures

Standard mitigation measures implemented during the study included the following:

1. Safety radii implemented for the Arctic Ocean cruise were specific for intermediate and deep water depths based on modeling and the acoustic calibration study conducted from the *Ewing* in the Gulf of Mexico in 2003 (Tolstoy et al. 2004a,b), as noted above and described in Appendix C.
2. Power-down or shut-down procedures were implemented when a marine mammal was sighted within or approaching the applicable safety radius while the G. guns were operating.

3. A change in vessel course and/or speed alteration was identified as a potential mitigation measure if a marine mammal was detected outside the safety radius and, based on its position and motion relative to the ship track, was judged likely to enter the safety radius. However, substantial alteration of vessel course or speed was not feasible during the Arctic Ocean cruise given the ice conditions and speed of the vessel (average speed = 4 kt during seismic operations). Power downs or shut downs were the preferred mitigation measures when mammals were sighted within or about to enter the safety radii.
4. A ramp-up procedure was implemented whenever operation of the 2 G. guns were initiated. Both guns were operated at half-volume for a total operating volume of 250 in^3 for 5 minutes before volume was increased to full (500 in^3). This resulted in an increase in source level of no more than 6 dB per 5 minutes—the maximum ramp-up rate authorized by NMFS during past L-DEO seismic cruises.
5. In order for seismic operations to start up during day or night, the full applicable safety radius must have been visible for at least 30 min. That precluded nighttime startups from a full shutdown, but in fact there were no periods of darkness until 23 Sept.

Special Mitigation Measures for the Arctic Ocean Cruise as required by NMFS

6. The G. guns were to be shut down if a North Pacific right whale, North Atlantic right whale, or Northeast Atlantic bowhead whale was sighted from the vessel, even if it was located outside the safety radius, because of the rarity and sensitive status of these species.

Updates to Monitoring and Mitigation Measures during the Cruise

One mitigation procedure, ramp up, was amended on 12 Aug. after application of the ramp-up process as specified in the IHA proved to be impractical. The 2 G. guns were arranged under a metal plate, or "bird", intended to help maintain their depth in the water. When ramping up as described in the IHA (one gun operating for 5 minutes at full volume, or 250 in^3, before activation of the second), the single operating G. gun tended to strike the non-operating gun and the depressor bird. There was concern that this could damage the equipment. The gun operators were instructed to operate each gun at half volume during ramp-up procedures, thereby producing an initial volume of 250 in^3 as described in the IHA. Both guns operating under equal pressure were more stable in the water and potential damage to the equipment during ramp up was greatly reduced. The amended procedure still met the objectives identified in the IHA issued to UAF on 5 Aug. 2005 (Appendix A), but with less risk of damage to the seismic equipment. Damage to gear was a substantial concern given the remote location of the survey and impossibility of acquiring replacements during the cruise.

Visual Monitoring Methods

Visual monitoring methods were designed to meet the requirements identified in the IHA (see above and Appendix A). The primary purposes of MMOs aboard the *Healy* were as follows: ***(1)*** Conduct monitoring and implement mitigation measures to avoid or minimize exposure of cetaceans to airgun sounds with received levels >180 dB re μPa (rms), or of pinnipeds to >190 dB. ***(2)*** Document numbers of marine mammals present, any reactions of marine mammals to seismic activities, and whether there was any possible effect on accessibility to subsistence hunters in Alaska. Results of the monitoring effort are presented in Chapter 4.

The visual monitoring methods that were implemented during this cruise were very similar to those used during previous L-DEO seismic cruises since 2003. In chronological order, these methods were described by Smultea, Holst et al. (2003), Smultea and Holst (2003), MacLean and Haley (2004), Holst (2004), Smultea et al. (2004), Haley and Koski (2004), MacLean and Koski (2005), Smultea et al. (2005), Holst et al. (2005a,b), and Ireland et al. (2005). The standard visual observation methods are described in Appendix E.

In summary, during the Arctic Ocean survey at least one MMO maintained a visual watch for marine mammals during all daylight hours while seismic surveys were underway. During this cruise, two visual observers were on duty for 46% of the time when visual watches were conducted. Visual observations were conducted from the *Healy*'s flying bridge during good weather or from the bridge during inclement weather. Nighttime watches were never necessary because there was no darkness until 23 Sept., and there were no seismic surveys during darkness. Observers focused their search effort forward of the vessel but also searched aft of the vessel while it was underway. Watches were conducted with the naked eye, Fujinon 7 × 50 reticle binoculars, and mounted 25 × 150 "Big-eye" binoculars. Appendix E provides further details regarding visual monitoring methods.

Acoustic Monitoring Methods

To complement the visual monitoring program, we listened to sounds received at sonobuoys as required by the IHA (Appendix A). As an adjunct to the geophysicists' use of sonobuoys, acoustic monitoring of sonobuoy transmissions was performed to gather information on the presence of marine mammals. Available data on occurrence of marine mammals far offshore in the Arctic (especially within the ice pack) are minimal. Visual monitoring typically is not effective during periods of bad weather or at night, and even with good visibility, is unable to detect marine mammals when they are below the surface or beyond visual range. Also, it was anticipated that the presence of the pack ice would further hinder the ability of MMOs to detect marine mammals visually. Acoustic detections can be used in addition to visual observations to improve detection of cetaceans. The use of acoustic monitoring during the survey had been strongly encouraged by biologists with the North Slope Borough in Barrow and was subsequently included as a stipulation of the IHA.

The sonobuoys included both AN/SSQ-57SPC omnidirectional buoys and additional unspecified U.S. Navy-surplus buoys. A sonobuoy was deployed approximately every four hours by the seismic crew. The received signals were transferred to the bridge by a low-power FM radio transmitter. The signals were available to MMOs via a portable FM radio and noise-canceling headphones. The sonobuoy output was also available via the ship's computer network using a "web radio" application, and was received and digitized on a data logging computer. An IBM Think Pad portable computer, equipped with acoustic software, was available to the MMOs to display and analyze the spectra of the received signals and to record the signals.

A MMO listened to the sonobuoy signals for ~10 min during each 30-min period of visual watch when a useable sonobuoy signal was available. Times when sonobuoy signals were monitored were noted, along with the other information routinely recorded by MMOs during visual watches. In practice, MMOs never heard marine mammal vocalizations while monitoring the sonobuoy signal. If there had been an acoustic encounter with marine mammal(s), the details would have been documented in a manner consistent with that used during acoustic monitoring in previous L-DEO cruises. Samples of the marine mammal sounds would also have been recorded via the laptop computer.

Analyses

Categorization of Data

Observer effort and marine mammal sightings were divided into several analysis categories related to vessel and seismic activity. The categories were similar to those used during other recent L-DEO seismic studies (e.g., Haley and Koski 2004; MacLean and Koski 2005; Smultea et al. 2005; Holst et al. 2005a,b; Ireland et al. 2005). These categories are defined briefly below, with a more detailed description provided in Appendix E.

In general, data were categorized as "seismic" or "non-seismic". "Seismic" included all data collected while the G. guns were operating. Non-seismic included all data obtained before the G. gun(s) were activated (pre-seismic) or >2 h after the G. guns were deactivated. Data collected during post-seismic periods from 3 min to 2 h after cessation of seismic activity were considered either "recently exposed" (3 –30 min) or "potentially exposed" (30 min–2 h) to seismic sound levels, and were excluded from analyses. Thus, the post-seismic data (3 min to 2 h after cessation of seismic) were not included in either the "seismic" or "non-seismic" categories. The 3 min cutpoint, about twice as long as during previous NSF-sponsored seismic cruises, was considered appropriate because of the relatively slow speed during seismic operations (~4 kt or 7.4 km/h, average). The 2-h cut-off of the post-seismic period was the same cut-off used during several other NSF-sponsored seismic cruises with relatively small seismic sources: the Aleutian, SE Alaska, Eastern Tropical Pacific off Central America, northwest Atlantic, and Norway cruises (Haley and Koski 2004; MacLean and Koski 2005; Holst et al. 2005a; Ireland et al. 2005).

This categorization system was designed primarily to distinguish potential differences in behavior and distribution of marine mammals with and without seismic surveys. The rate of recovery toward "normal" during the post-seismic period is uncertain. Marine mammal responses to seismic sound likely diminish with time after the cessation of seismic activity. The end of the post-seismic period was defined so as to be sufficiently long (2 h) after cessation of airgun activity to ensure that any carry-over effects of exposure to sounds from the 2 G. guns would have waned to zero or near-zero by then. The reasoning behind these categories was explained in MacLean and Koski (2005) and Smultea et al. (2005) and is discussed in Appendix E.

Estimation of Densities

The sightings of marine mammals obtained during this project cannot be used to estimate numbers and densities of marine mammals near the seismic vessel because of biases that were not present during earlier cruises. There were two major biases. ***(1)*** The first resulted from *Oden* traveling ahead of *Healy* much of the time when ice cover was high. Many seals that were on the ice in front of *Oden* no doubt dove into the water where most would not be visible to observers on *Healy*. (Seals are much more readily sighted when on the ice than when in the water.) This is a major bias because "Distance Sampling" procedures, which are used to estimate densities from sightings, assume that all or most of animals on the track line are seen by observers. However, when *Oden* was ahead of *Healy,* many of those close to the trackline would not be visible to observers on the *Healy* because of prior disturbance by *Oden*. ***(2)*** The second bias was caused by the variable amount of open water along the ship track, and the fact that the ship(s) tended to move through leads and polynyas of open water, often with ice at varying distances to the side. The heterogeneity of habitat as a function of lateral distance prevents us from using data on the lateral distances of the sightings from the trackline to estimate densities of hauled out and swimming seals. The variable presence of ice to the side of the trackline resulted in truncation of the in-water and on-ice sightings at variable and often unknown distances. The sighting distribution of swimming seals was right-truncated by solid ice at variable distances to the side of the track line. The sighting distribution of hauled-out seals was variably left-truncated by open water near the ship.

Because we could not use the sighting data collected during the cruise to estimate densities of marine mammals near the seismic activity, we used the densities from earlier studies that were summarized in the IHA application for this study (see Appendix I). These density estimates resulted in higher estimates of "take" than would be expected from the low numbers of sightings by the observers during this cruise.

Estimating Numbers Potentially Affected

For purposes of the IHA, NMFS assumes that any marine mammal that might have been exposed to G. gun pulses with received sound levels ≥160 dB re 1 μPa (rms) may have been disturbed. When calculating the number of mammals potentially affected, the nominal 160 dB radii for the depth of water in which the survey took place was used (Table 3.1).

Two approaches were applied to estimate the numbers of marine mammals that may have been exposed to sound levels ≥160 dB re 1 μPa (rms):

1. Estimates of the numbers of potential *exposures* of marine mammals, and
2. Estimates of the number of different *individual* mammals exposed (one or more times).

The first method ("exposures") involved multiplying the following three values for each airgun configuration in use: (A) km of seismic survey; (B) width of area assumed to be ensonified to ≥160 dB (2 × 160 dB radius); and (C) densities of marine mammals estimated from past studies as summarized in the IHA application and Appendix I. Thus, areas of water ensonified on more than one occasion, due to overlapping or adjacent tracklines, were counted in the area calculation as many times as they were ensonified.

The second approach ("individuals") involved multiplying the same three values, except that areas ensonified to ≥160 dB on more than one occasion, due to overlapping tracklines, were counted only once. The area of water considered ensonified in this calculation is therefore smaller than in the first calculation.

The two approaches can be interpreted as providing maximum and minimum (respectively) estimates of the number of marine mammals that would have been exposed to sound levels ≥160 dB re 1 μPa (rms) if they did not show avoidance reactions. The actual number is probably somewhere between these two estimates. This approach was originally developed to estimate numbers of seals potentially affected by seismic surveys in the Alaskan Beaufort Sea (Harris et al. 2001). The method has recently been used in various L-DEO reports to NMFS (e.g., Haley and Koski 2004; Smultea et al. 2004, 2005; MacLean and Koski 2005; Holst et al. 2005a,b). The methodology is described in detail in these past reports and in Appendix E.

4. MARINE MAMMALS

Introduction

This chapter provides background information on the occurrence of marine mammals in the project area, and describes the results of the marine mammal monitoring program. In addition, numbers of marine mammals potentially affected during project operations within the study area are estimated. The study area, for the purposes of marine mammal data analyses, was the actual seismic survey area (see Fig. 1.1, 4.1) including the area traversed during the 2 h before seismic operations began and 2 h after the end of the final seismic survey.

Seismic survey activities occurred along 2273 km of trackline over a total of 294 h (Fig. 1.1, 4.1; Table ES.1). In total, 4768 km of visual observations and 739 km of acoustic monitoring effort were conducted within the study area. "Useable" survey conditions occurred during 70% (in km; 66% in h) of the total visual effort (Table ES.1, Fig. 4.1). "Useable" effort excluded periods 3 min to 2 h after the G. guns were turned off, poor visibility conditions (visibility <2 km or extensive glare), and Bf >5. The project provided data on the summer occurrence, distribution, and abundance of marine mammals in intermediate depth (100–1000 m) and deep (>1000 m) waters of the Arctic Ocean, an area where few systematic survey data had been collected previously.

The marine mammals known to occur along the cruise trackline across the Arctic Ocean belong to four taxonomic groups: odontocetes (toothed cetaceans, including the beluga and sperm whales), mysticetes (baleen whales), pinnipeds (seals and walruses), and the polar bear. Seventeen cetacean species and seven species of pinnipeds are known to occur along the cruise trackline, along with the polar bear. Of the total 25 species, seven (all cetaceans) are listed under the U.S. Endangered Species Act (ESA) as endangered: the sperm, bowhead, humpback, blue, fin, and sei whales, and perhaps the North Atlantic right whale. Appendix F summarizes the abundance, habitat, and conservation status of the marine mammal species likely to occur in the cruise area.

Monitoring Effort and Marine Mammal Encounter Results

This section summarizes the visual and acoustic monitoring effort and sightings from the *Healy* during the Arctic Ocean seismic survey from 10 Aug. to 26 Sept. 2005. There were no acoustic detections. Summaries of results of visual monitoring are presented here, with more detailed data presented in Appendices G and H, including survey effort in both kilometers and hours. A general summary of effort and sightings is shown in Table ES.1. Marine mammals observed during transits outside the study area are summarized in Table G.4.

Visual Survey Effort

All *Healy* survey tracks are plotted by seismic activity (G. guns on or off) in Figure 1.1 and by visual survey effort (useable, non-useable, none) in Figure 4.1. During 7381 km of *Healy* operations during the cruise, 3338 km of useable visual observations were made (Table ES.1). Useable survey effort, subdivided by G. guns on or off and water depth strata, is shown in Appendix G.1. MMOs observed primarily from the bridge (84% of watch time), with the remaining observations conducted from the flying bridge and Aloft Conn.

Beaufort Wind Force (sea state) during observations ranged from 0 to 2 within the study area, with 88% (in h) of the observation effort during conditions of Bf = 0. The prevailing low sea state was due to

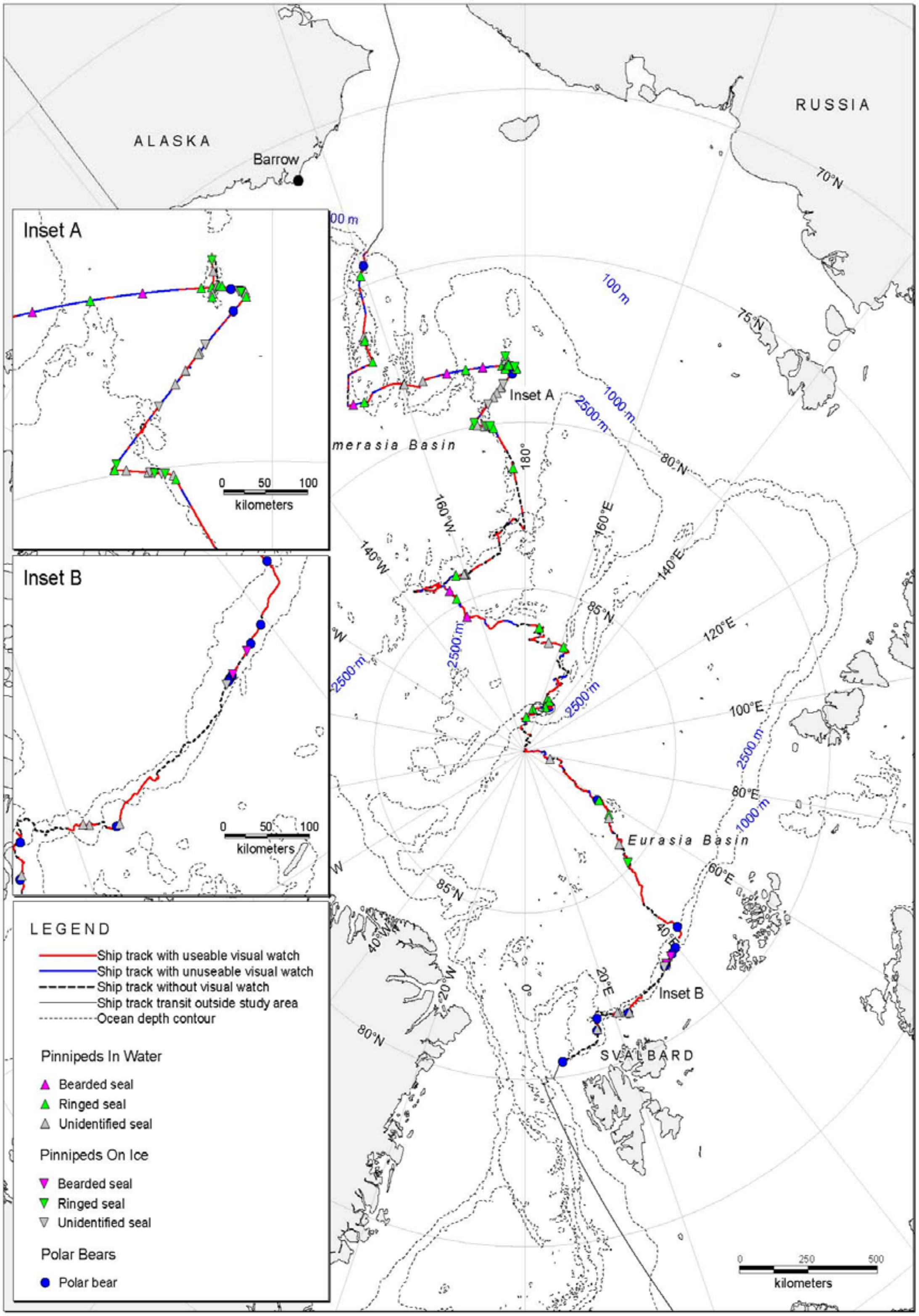

FIGURE 4.1. The *Healy* ship tracks and Arctic Ocean study area showing periods when G. guns were on and off during the Arctic Ocean seismic survey, 5 Aug. – 30 Sept. 2005. The cruise originated in Dutch Harbor, Alaska, and ended in Tromsø, Norway.

heavy ice coverage and lack of open water throughout the survey. None of the observations within the study area were deemed "non-useable" because of high Beaufort Wind Force.

Visual Sightings of Marine Mammals and Other Vessels

Numbers of Marine Mammals Seen.—An estimated 102 individual marine mammals were seen in 97 groups through the study area (Table 4.1). Three different marine mammal species were identified with ringed seals being the most abundant (n = 35 individuals in 35 groups), followed by polar bears (n = 24 in 19 groups; Table 4.1). In addition, seven groups (7 individuals) of bearded seals were observed. Of the 42 seals identified in the study area, 35 (or 83%) were ringed seals. Most of the unidentified seals (n = 36 individuals in 36 groups) were likely ringed seals, given the visual monitoring results and the known occurrence of this species throughout the study area. However the unidentified seals moved too rapidly or were too far away for the observer to make a positive identification. A dead seal was sighted on 18 Aug. on the pack ice while seismic operations were being conducted. It appeared to be an old polar bear kill, because its carcass was partially eaten and the remaining flesh appeared to be decaying. The seal's death was not attributed to seismic survey activity. A dead Pacific walrus was also encountered while the *Healy* was in transit to the study area on 8 Aug. The animal was floating, bloated, and appeared to have been dead for ~2 weeks. This carcass was observed two days in advance of any seismic operations. A detailed list of sightings is provided in Appendix G.3.

Most of the 97 sightings (88% or 86 groups) made within the study area were "useable" (Table 4.1, 4.2). These "useable" sightings, along with the corresponding effort data, are the basis for the ensuing analyses comparing sighting rates and behaviors of marine mammals during seismic and non-seismic periods.

Sightings with G. Guns On.—Of the total 97 sightings, 62 were made while the G. guns were operating, 31 were made during non-seismic periods, and the remaining 4 were noted during "post-seismic" periods (Tables ES.1, 4.1).

Power downs were requested on three occasions when seals were sighted in the water within the 190 dB safety radius around the operating airguns. During one of these three incidents, the G. guns were fully shut down because of a misunderstanding between the gunners and MMO. Further details on these encounters are provided later in this chapter (see *Marine Mammals Potentially Exposed to Sounds ≥180 dB*) and in Appendix H.

Sighting Rates.—Sighting rates (# groups sighted per unit effort) during various types of MMO effort are presented in Table 4.3. Based on the number of groups seen per kilometer, the sighting rate was nearly twice as high during seismic operations as during non-seismic conditions (Table 4.3). These results were anticipated because the seismic operators tended to take advantage of lighter ice conditions, which seals prefer, to conduct seismic activities. Operating seismic gear through leads and polynyas reduced the danger of damaging equipment in the ice. Seals favor these areas where they can freely enter the water to feed and can escape polar bears. Bears presumably favor the same areas because of the higher density of seals. The highest useable sighting rates were for pinnipeds in water and pinnipeds on ice during seismic periods (both = 16.3 seals/1000 km). The greatest difference between useable sighting rates was that between pinnipeds in water during non-seismic and seismic periods. The sighting rate of pinnipeds in the water was more than 7 times higher during seismic than during non-seismic periods. This reflects the fact that seismic operations were conducted along leads or in areas of lighter ice, which seals prefer. It is also probable that hauled-out seals entered the water as the vessel approached.

TABLE 4.1. Numbers of sightings and of individual marine mammals, both ***(A)*** total and ***(B)*** useable[a], observed from the *Healy* in the study area during the Arctic Ocean cruise, 10 Aug.–26 Sept. 2005.

	Non-Seismic		Post-Seismic		Seismic		Total	
	Groups	Indiv.	Groups	Indiv.	Groups	Indiv.	Groups	Indiv.
A. All Sightings								
Pinnipeds in Water								
Bearded Seal	0	0	0	0	5	5	5	5
Ringed Seal	3	3	1	1	25	25	29	29
Unidentified Seal	12	12	0	0	16	16	28	28
Pinnipeds on Ice								
Bearded Seal	2	2	0	0	0	0	2	2
Ringed Seal	1	1	1	1	4	4	6	6
Unidentified Seal	1	1	0	0	7	7	8	8
Total Pinnipeds	19	19	2	2	57	57	78	78
Ursids								
Polar Bears	12	15	2	2	5	7	19	24
B. Useable[a] Sightings								
Pinnipeds in Water								
Bearded Seal	0	0	N/A	N/A	4	4	4	4
Ringed Seal	3	3	N/A	N/A	23	23	26	26
Unidentified Seal	12	12	N/A	N/A	14	14	26	26
Pinnipeds on Ice[b]								
Bearded Seal	2	2	N/A	N/A	0	0	2	2
Ringed Seal	1	1	N/A	N/A	4	4	5	5
Unidentified Seal	1	1	N/A	N/A	7	7	8	8
Total Pinnipeds	19	19	N/A	N/A	52	52	71	71
Ursids[b]								
Polar Bears	11	12	N/A	N/A	4	6	15	18

Note: N/A means not applicable.
[a] Useable sightings are those made during useable daylight periods of visual observation, as defined in *List of Acronyms and Abbreviations*.
[b] Sightings of pinnipeds on ice and polar bears that occurred during "useable" sighting conditions.

TABLE 4.2. Number of marine mammal sightings from the *Healy* during the Arctic Ocean seismic survey, 10 Aug. – 26 Sept. 2005, and number that were "useable" in analyses[a]. Numbers in parentheses are numbers of individuals.

	# Sightings (# Indiv.)	
Species	All	Useable[a]
Bearded seal	7 (7)	6 (6)
Ringed seal	35 (35)	31 (31)
Unidentified seal	36 (36)	34 (34)
Polar bear	19 (24)	15 (18)
Total	**97 (102)**	**86 (89)**

[a] Useable detections are those made during useable daylight visual observations; see *Acronyms and Abbreviations* for the definition of "useable" observation effort.

TABLE 4.3. Encounter rates for sightings from the *Healy* during the Arctic Ocean seismic survey, 10 Aug. – 26 Sept. 2005.

	Non-Seismic			Post-Seismic			Seismic			Total		
Effort Type	No. of Detect.	Effort (km)	Detection Rate (No./1000 km)	No. of Detect.	Effort (km)	Detection Rate (No./1000 km)	No. of Detect.	Effort (km)	Detection Rate (No./1000 km)	No. of Detect.	Effort (km)	Detection Rate (No./1000 km)
Useable[a]												
Pinnipeds in water	4	1741	2.3	-	-	-	26	1597	16.3	30	3338	9.0
Pinnipeds on ice	15	1741	8.6	-	-	-	26	1597	16.3	41	3338	12.3
Polar bears	11	1741	6.3	-	-	-	4	1597	2.5	15	3338	4.5
Total useable	*30*	*1741*	*17.2*	-	-	-	*56*	*1597*	*35.1*	*86*	*3338*	*25.8*
Non-Useable[b]												
Pinnipeds in water	-	-	-	1	373	2.7	5	676	7.4	6	1431	4.2
Pinnipeds on ice	-	-	-	1	373	2.7	-	-	-	1	1431	0.7
Polar bears	1	382	2.6	2	373	5.4	1	676	1.5	4	1431	2.8
Total non-useable	*1*	*382*	*2.6*	*4*	*373*	*10.7*	*6*	*676*	*8.9*	*11*	*1431*	*7.7*
All	**31**	**2123**	**14.6**	**4**	**373**	**10.8**	**62**	**2273**	**27.3**	**97**	**4768**	**20.3**

[a] Useable detections are those made during useable daylight visual observations; see *Acronyms and Abbreviations* for the definition of "useable" observation effort.

[b] Includes the "Post-seismic" category.

The presence of fog (visibility <2 km) was the most common reason that sightings were considered non-useable. During seismic periods, the detection rate in non-useable periods was about ¼ of that in useable periods, consistent with what would be expected during periods of poor vs. good visibility (Table 4.3). For non-seismic periods, the difference in detection rate between non-useable and useable periods was even greater (Table 4.3).

Other Vessels—While the *Healy* and *Oden* were working in tandem on 1–23 Sept., the vessels were typically within 5 km of each other and often as close as a few hundreds of meters from each other. The location and proximity of the *Oden* were extremely variable, and probably had some effect on the number of sightings and the behavior of marine mammals that were sighted. This effect, however, was not apparent to the MMOs. Other than the *Oden*, only one small fishing boat was observed while MMOs were on watch, and that was close to Dutch Harbor, outside the study area.

Acoustic Monitoring Results

Acoustic monitoring was conducted for a total of 739 km (98 h) during the study period (Table ES.1). All acoustic monitoring occurred during visual observations and ~68% coincided with useable visual effort (as defined earlier); the remaining 32% occurred during "non-useable" periods (e.g., visibility <2 km). Acoustic monitoring occurred during 33% of the time that airguns were operating.

While listening to the output of the sonobuoys, the observers could hear ship noises including the G. gun pulses and the periodic "chirp" generated by the sonar. Grinding and scraping sounds from ice breaking usually were also audible. As the distance between the ship and sonobuoy increased, the vessel sounds faded, but the sound caused by pieces of ice colliding in the wake of the ship was often heard. No marine mammal calls were detected during the Arctic Ocean seismic survey.

Distribution of Marine Mammals

Marine mammal sightings in the study area are plotted in Figure 4.1. As noted earlier, to our knowledge, no systematic vessel-based surveys specifically for marine mammals had been conducted across the Arctic Ocean prior to this survey.

Observations during the Arctic Ocean study indicate that, as expected, the ringed seal was the most abundant species in the study area. The large number of ringed seal sightings was expected based on limited previous survey efforts. Ringed seals were seen throughout the survey area wherever visual observations occurred, including before, during, and after seismic operations (Fig. 4.1; Appendix G.3). Numerous ringed seal sightings (n = 15) occurred north of Alaska between 78.3° and 80.2°N where ice coverage averaged 80%, which might be considered the ice margin. Not surprisingly, the lowest concentration of marine mammal sightings occurred along the more northerly parts of the trackline where ice coverage averaged 96% (between 80.2°N north of Alaska and 81.5°N north of Svalbard).

Most of the polar bears sighted in the study area were observed during the last days of the seismic survey, 23–26 Sept. Within that period, we encountered 15 of the 19 polar bear sightings (16 of 24 individuals) within the study area. Two of those polar bear sightings were of individuals feeding on seals. The average ice coverage of that area, considered part of the ice margin, was ~73%.

Marine Mammal Behavior

The data collected during visual observations provide information about behavioral responses of marine mammals to the seismic survey. The relevant data include estimated closest observed points of approach (CPA) to the vessel, movement relative to the vessel when the G. gun was and was not firing, and observed behavior of animals at the time of the initial sightings.

Closest Observed Point of Approach

There was no statistical difference between the distance at which pinnipeds in water were seen when the G. guns were off versus when on, considering only useable sightings (Wilcoxon rank sum test, W = 304, P = 0.96; Table 4.4). The mean CPA for pinnipeds on ice was similar to that of polar bears during both seismic and non-seismic periods. The mean CPA during seismic periods, as presented in Table 4.4, may be underestimated if some animals avoided the G. gun at distances beyond those where they could be detected by MMOs. However, there was no evidence of such avoidance. Sighting rates were actually higher during seismic than non-seismic periods (Table 4.3).

Although most sample sizes are small, the sighting-distance data from this study are the reverse of those from many previous seismic studies. In other studies, marine mammals usually tend to be observed at greater distances from the vessel and lower sighting rates when the airguns are operating than when the airguns are silent (e.g., Smultea et al. 2004; Haley and Koski 2004; MacLean and Koski 2005; Holst et al. 2005a,b). The relatively small sound source used during this study, the unique environmental conditions (ice cover), and the types of animals present in this study area may have been responsible for these differences.

TABLE 4.4. Closest observed points of approach (CPA) of useable marine mammal sightings to the G. guns during non-seismic and seismic periods during the Arctic Ocean cruise, 5 Aug.–30 Sept. 2005.

		Non-seismic				Seismic			
Group[a]	No. of Groups	Mean CPA (m)	s.d.	*n*	Range (m)	Mean CPA (m)	s.d.	*n*	Range (m)
Pinnipeds in Water	56	238	102	15	120 - 439	284	106	41	92 - 635
Pinnipeds on Ice	16	1846	1171	4	250 - 3024	794	359	11	271 - 1500
Polar Bears	15	1675	1389	11	193 - 4087	1103	888	4	128 - 2270

[a] Includes only useable sightings as defined in *Acronyms and Abbreviations.*

- Displacement of marine mammals is presumably related to the size of the sound source, and would be expected to be less in a project like this one that involved a relatively small sound source; however, that cannot be assessed based on this study alone.
- The tendency for seismic operations to occur in leads and polynyas, where seals and polar bears may be most abundant, could account at least in part for higher sighting rates during seismic operations.
- The ringed seal, the most common species of marine mammal in the area traversed during this study, is known from prior studies to be relatively non-responsive to airgun sounds (Harris et al. 2001; Miller et al. 2005).
- The polar bears observed during this study were on the ice, where they would presumably be unaffected by airgun sounds.

Categories of Behavior

Marine mammal behavior is difficult to observe because individuals and/or groups are often at the surface only briefly. This causes difficulties in resighting those animals, and in determining whether two sightings some minutes apart are repeat sightings of the same individual(s). Only limited behavioral data were collected during this project because marine mammals were often seen at a distance from the vessel, and they were typically not tracked for long distances or durations while the vessel was underway. The two parameters that were examined quantitatively to assess potential seismic effects on behavior were the categories of behavior and of movement when the animal(s) were first observed (see Appendix E for variables and definitions). The CPA distance recorded for each sighting was also an indicator of behavior (see above and Appendix E).

Sample sizes within this one cruise were small and we are not aware of any previous study that has provided comparable data on marine mammal behavior in response to airgun operations within the polar ice pack. However, when these results are combined with results from other comparable cruises, the data may be useful in assessing behavioral reactions of arctic marine mammals to seismic sounds. Results are presented in Tables 4.5 and 4.6.

Movement.—During both seismic and non-seismic periods, pinnipeds (mainly ringed seals) in the water were most often seen swimming away from the vessel (39% of sightings; Table 4.5). The second most frequently-observed movement in relation to the vessel was swimming perpendicular to the vessel (23% sightings). The movement of polar bears and pinnipeds first observed on ice was always categorized as hauled out and is therefore not present in Table 4.5. However, these animals' reactions (or lack of reactions) to the vessel, during both seismic and non-seismic periods, are evident from the behavior data presented below (Table 4.6).

TABLE 4.5. Movements of useable marine mammal sightings during non-seismic and seismic periods during the Arctic Ocean cruise, 3 Aug.–30 Sept. 2005. See Appendix E for definitions of movement categories.

	Movement Relative to Vessel							
Group[a]	Mill	Swim Perpen-dicular	Swim Away	Swim Parallel	Swim Toward	No movement	Unknown	Total
Pinnipeds in Water								
Non-seismic	3	5	6	0	0	0	1	**15**
Seismic	9	8	16	3	2	3	0	**41**
Total	**12**	**13**	**22**	**3**	**2**	**3**	**1**	**56**

[a] Includes only useable sightings are as defined in *Acronyms and Abbreviations*.

TABLE 4.6. Comparison of first observed behavior of useable marine mammal groups during non-seismic and seismic periods within the study area of the Arctic cruise, 3 Aug.–30 Sept. 2005. See Appendix E for definitions of behavior.

Group[a]	Swim	Dive	Thrash / Flee	Log / Rest	Feed	Walk Away	Walk Towards	No Movement	Total
Pinnipeds in Water									
Non-seismic	8	1	2	4	0	0	0	0	**15**
Seismic	17	5	1	18	0	0	0	0	**41**
Total	**25**	**6**	**3**	**22**	**0**	**0**	**0**	**0**	**56**
Pinnipeds on Ice									
Non-seismic	0	0	0	3	0	0	0	1	**4**
Seismic	0	0	0	11	0	0	0	0	**11**
Total	**0**	**0**	**0**	**14**	**0**	**0**	**0**	**1**	**15**
Polar Bears									
Non-seismic	0	1	1	4	2	2	1	0	**11**
Seismic	0	0	0	1	0	1	2	0	**4**
Total	**0**	**1**	**1**	**5**	**2**	**3**	**3**	**0**	**15**

[a] Includes only useable detections as defined in *Acronyms and Abbreviations*.

First Observed Behavior.—Across all categories of animals, the most common "first observed behavior" during both seismic and non-seismic periods was logging/resting (Table 4.6). Logging was the first observed behavior for 37% of sightings during non-seismic periods, and 54% during seismic operations. However, pinnipeds that were observed in the water were about as likely to be actively swimming as they were to be resting at the surface (Table 4.6). Pinnipeds first observed on the ice usually remained hauled out while the vessel passed (Table 4.6). Polar bears were observed actively feeding on ringed seals on two occasions, and the carcass of a third seal was also sighted.

Mitigation Measures Implemented

A total of three power downs of the 2 G. guns were requested due to marine mammal sightings within the nominal 180 and 190 dB safety radii during the Arctic Ocean cruise (Table 4.7). On one occasion, a shut down was implemented instead of a power down because of a misunderstanding between the MMO and the seismic operator. All three sightings were of individual pinnipeds. Each sighting occurred in intermediate water depths (100-1000 m), where the defined safety radius for pinnipeds was 150 m (Table 3.1).

TABLE 4.7. List of power downs (PD) and shut downs (SZ) of the GI guns implemented for marine mammals sighted in or near the safety radii during the Arctic Ocean seismic cruise, 10 Aug.– 26 Sept. 2005.

Species	Group size	Date (2005)	Water depth (m)	Initial sighting distance to MMO	Movement[a]	Dove? (yes/no)	Total G. gun volume prior to SZ or PD (in in^3)	Estimated 190-dB radius	CPA(m) to operating G. guns before mitigation	Mitigation measure taken (PD or SZ)	Estimated maximum received sound exposure (dB)	No. indiv. exposed to >190 dB re 1 μPa (rms)[b]
Ringed Seal	1	12-Aug	500	45	MI	Yes	500	150	92	PD	190	1
Bearded Seal	1	17-Aug	481	40	SP	Yes	500	150	136	PD	190	1
Ringed Seal	1	19-Aug	854	109	PE	Yes	500	150	148	SZ	190	1

[a] Initial movement of group relative to the vessel: MI = milling, SP = swimming parallel, PE = across bow.

[b] Number of individuals that came within estimated 190 dB radius for the volume of G. guns in use at the time (see text for details).

[c] A power down was called for, but a shut down implemented due to misunderstanding.

Both power downs were attributable to seals that were already within the safety zone when first sighted (ringed seal, 12 Aug.; bearded seal, 17 Aug.). • Because of difficulty contacting the gunners after the ringed seal was observed, the G. guns were not powered down until two minutes after the seal was seen diving ~92 m from the operating guns. The ringed seal was presumably exposed to sound levels ≥190 dB re 1 μPa (rms) when it dove. • The bearded seal "sank" into the water just seconds before a power down was enacted, when it was ~136 m from the seismic source. The extent of the 190 dB received level for the G. guns deepens as distance from the source increases (Fig. C.1). It is very unlikely that the bearded seal would have been exposed to >190 dB unless it was well below the surface before the G. guns were powered down, which is very unlikely. If the bearded seal was exposed to >190 dB noise levels, the exposure was brief.

The shut down was implemented on 19 Aug. after a ringed seal was seen diving ~148 m from operating guns. It is unlikely that the ringed seal was exposed to sound levels ≥190 dB when it dove. It was near the perimeter of the safety zone, where it could only have been exposed to those levels if it dove deeply before seismic operations were terminated. Appendix H provides further details concerning the power downs and shut down.

Estimated Number of Marine Mammals Present and Potentially Affected

It is difficult to obtain meaningful estimates of "take by harassment" for several reasons: ***(1)*** The relationship between numbers of marine mammals that are observed and the number actually present is uncertain. ***(2)*** The most appropriate criteria for "take by harassment" are uncertain and presumably variable among species and situations. ***(3)*** The distance to which a received sound level exceeds a specific criterion such as 190 dB, 180 dB, 170 dB, or 160 dB re 1 μPa (rms) is variable. It depends on water depth, source depth, water-mass and bottom conditions, and—for directional sources—aspect (Greene 1997; Greene et. al. 1998; Burgess and Greene 1999; Caldwell and Dragoset 2000; Tolstoy et al. 2004a,b). ***(4)*** The sounds received by marine mammals vary depending on their depth in the water, and will be considerably reduced for animals at or near the surface (Greene and Richardson 1988; Tolstoy et al. 2004a,b) and further reduced for animals that are on the ice.

In this study, there were additional factors to consider. Many of the sightings were of animals (pinnipeds and polar bears) on pack ice, where they were not exposed to underwater sound. Also, the fact that the ship tended to travel along leads and through polynyas, especially when operating the G. guns, means that sighting rates during seismic and non-seismic periods are not directly comparable. Both seals and polar bears would be expected to be more common in the leads and polynyas where seismic operations tended to occur. The fact that *Oden* traveled ahead of *Healy* during a fraction of the traverse also was expected to affect the observations from *Healy*. Within the study area, no cetaceans were seen, and all polar bears observed within the study area were on the ice where they would not be exposed to high sound levels from the G. guns.

Disturbance and Safety Criteria

Table 3.1 shows the distances at which various sound levels are estimated to be received from two 250 in^3 G. guns, distinguishing between two different water depth categories. The predicted 160 and 170-dB radii are assumed disturbance criteria, and they are based on modeling and limited acoustic measurements in the northern Gulf of Mexico (Tolstoy et al. 2004a,b). The 180 and 190 dB radii are safety radii, used in determining when mitigation measures were required. During this and many other recent projects, NMFS has required that mitigation measures be applied to avoid or minimize the exposure of cetaceans and pinnipeds to impulse sounds with received levels ≥180 dB and ≥190 dB re 1 μPa (rms), respectively. The safety and disturbance radii were used after the field season to estimate numbers of marine mammals exposed to various received sound levels.

This section applies two methods to estimate the number of pinnipeds and cetaceans exposed to seismic sound levels strong enough that they might have caused disturbance or other effects. The procedures include ***(A)*** minimum estimates based on direct observations, and ***(B)*** estimates based on seal and cetacean densities obtained during earlier studies in the Beaufort Sea pack ice. The actual number of individuals exposed to, and potentially affected by, strong seismic survey sounds likely was between the minimum and maximum estimates provided below.

Estimates from Direct Observations

The number of marine mammals observed close to the *Healy* during the Arctic Ocean survey provides a minimum estimate of the number potentially affected by seismic sounds. This is likely an underestimate of the actual number potentially affected. Some animals probably moved away before coming within visual range, and not all of those that remained would have been seen by observers.

Seals Potentially Exposed to Sounds ≥190 dB re 1 µPa (rms).—During this project, three marine mammals were sighted within the small safety radius around the G. guns. Any or all of the three seals observed within the safety radius may have received sound levels in excess of 190 dB, but only one of them was likely to have been exposed to those levels. Each of the seals was seen diving within the 190 dB sound radius. However, in two cases the seals submerged near the perimeter of the safety zone where they would not have been exposed to 190 dB unless they dove well below the surface before mitigation was implemented.

The estimated 180-dB and 190-dB radii shown in Table 3.1 are the *maximum* distances from the G. guns where sound levels were expected to be ≥180 or ≥190 dB re 1 µPa (rms). These distances would apply at the water depth (and in the directions) with maximum received level. Thus, there are complications in assessing the maximum level to which any specific individual mammal might have been exposed:

- Near the water surface, received sound levels are considerably reduced because of pressure-release effects. In many cases, it is unknown whether animals seen at the surface were earlier (or later) exposed to the maximum levels that they would receive if they dove.
- Some marine mammals may have been within the predicted safety radii while underwater and not visible to observers, and subsequently seen outside these radii. The direction of movement as noted by MMOs can give some indication of this.
- The MMO station on the bridge was ~100 m forward of the G. guns, and the tip of the *Healy's* bow was ~128 m away from the G. guns. The safety zone was not centered on the observer's station, but rather on the G. guns. This offset in location between G. guns and observer was accounted for in the observer's decisions regarding whether it was necessary to shut down the G. guns for sightings immediately forward or astern.

Marine Mammals Potentially Exposed to Sounds ≥160 dB re 1 µPa (rms).—Forty-one groups of pinnipeds were sighted in the water under "useable" conditions during the Arctic Ocean cruise when the G. guns were operating (Table ES.1; Appendix G.3). All 41 groups were believed to be unique groups. Thirty-eight of those groups (38 individuals) are believed to have entered the ≥160 dB radius (see Appendix G.3 for sightings). Each of these 38 individual seals are also presumed to have been exposed to ≥170 dB sound levels, based on water depth and closest observed point to the G. guns. Seven of the total "useable" pinniped sightings occurred in intermediate-depth (100-1000 m) water and 34 sightings occurred in deep (>1000 m) water.

Estimates Extrapolated from Density

The numbers of mammals directly sighted during the Arctic Ocean study no doubt underestimated the actual numbers present because some animals present near the trackline would not be seen by the observers. Some cetaceans may have been present despite the lack of cetacean sightings. During daylight, animals are missed if they are below the surface when the ship is nearby. Also, some other mammals, even if they surface near the vessel, are missed because of limited visibility, intervening ice, glare, or other factors limiting sightability. High sea state (Bf) was not a significant factor during this cruise because waves were dampened by the ice.

Furthermore, some animals may have avoided the area near the seismic vessel while the G. guns were firing (see Richardson et al. 1995; Stone 2003; Gordon et al. 2004; Smultea et al. 2004). Within the assumed 160–170 dB radii around the source (i.e., ~5000–1600 m in waters >100 m deep), the distribution and behavior of pinnipeds and cetaceans may have been altered as a result of the seismic survey. This could occur as a result of reactions to the G. guns, or as a result of reactions to *Oden* or *Healy*. The extent to which the distribution and behavior of pinnipeds might be affected by the G. guns is uncertain, given variable previous results (Thompson et al. 1998; Harris et al. 2001; Miller et al. 2005). However, it is safe to assume that some pinnipeds that were on the ice as the two ships approached would have gone into the water in response to *Oden* before they were in view of observers on *Healy*. Likewise, it is safe to assume that—if any cetaceans were approached during the seismic survey—some of those animals would have moved away before they were in view.

The methodology used to estimate the areas exposed to received levels ≥160 dB, ≥170 dB, ≥180 dB and ≥190 dB was described briefly in Chapter 3 *Analyses* and in further depth in Appendix E. Densities were based on earlier surveys conducted in the pack ice in the Beaufort Sea (Kingsley 1986) and elsewhere. It is not known how these densities might have compared to the actual densities in the survey area, but the previous work did not extend nearly as far north.

The aforementioned densities were used to estimate both the number of *individual* marine mammals exposed to 160, 170, 180, and 190 dB, and the number of *exposures* of different individual marine mammals. (Because the present survey was more or less linear, with little doubling back across or near previous tracklines, the two types of estimates are not much different.) These numbers provide estimates of the number of animals potentially affected by seismic operations, as described in Chapter 3 and Appendix E.

The estimates provided here are based on the actual amount of seismic surveying during this project. In contrast, the estimates provided in the IHA application and EA for this project (LGL Ltd. 2005a,b) were based on the then-anticipated amount of survey, with an allowance for the possibility that some lines would be surveyed more than once. The estimates in the IHA application and EA assumed that there would be more seismic surveying than actually occurred. Thus, the present estimates are lower than those in the EA and IHA Application even though they are based on the same assumed density data. In addition, the following estimates assume that all mammals present were well below the surface where they would be exposed to the sound levels predicted in Table 3.1 at a given distance. In fact, some pinnipeds were hauled out on the ice, and remained there as the ship passed, and some pinnipeds and cetaceans in the water might remain close to the surface, where sound levels would be reduced by pressure-release effects (Greene and Richardson 1988). Finally, some pinnipeds and cetaceans may have moved away from the path of the *Healy* before it arrived, either because *Oden* frequently traveled in front of *Healy* to break ice, or because of an avoidance response to the approaching *Healy* and its G. guns. Thus, the following estimates, though lower than those in the IHA Application and EA, are nonetheless likely to overstate actual numbers exposed to various received sound levels.

TABLE 4.8. Estimated numbers of exposures, and estimated minimum numbers of individual pinnipeds (ringed seals, spotted seals and bearded seals) that might have been exposed, to sounds with received levels ≥160 dB, ≥170, ≥180 dB and ≥190 dB re 1 µPa (rms). These estimates assume that all pinnipeds were in the water, and that they did not move away from the G. guns. Estimates are based on densities of pinnipeds in marginal pack ice, from Kingsley (1986), with downward adjustment for the lower densities in the polar pack ice. No spotted seals were expected to occur within the polar ice pack. Also shown in boldface is the "harassment take" authorized by NMFS under the IHA.

Exposure level in dB re 1 µPa (rms)	Estimated numbers in pack ice margin areas		Estimated numbers in polar pack ice		Estimated total		**Requested take**
	Exposures	Individuals	Exposures	Individuals	Exposures	Individuals	
≥160	3930	3430	73	71	4003	3501	**4811**
≥170	1139	1101	20	20	1159	1121	
≥180	338	331	6	6	344	337	
≥190	102	99	1	1	104	100	

Pinnipeds.—Table 4.8 summarizes the estimated numbers of ringed seals, bearded seals, and spotted seals (almost exclusively ringed seals) that might have been exposed to received sounds with levels ≥160 dB and ≥170 dB relative to the number of "takes" requested in the IHA application. The data used to calculate these numbers, for non-seismic as well as seismic periods, are presented in Appendix I for the criteria of interest. As in the IHA application and EA, we have assumed that ringed seal density in the polar pack ice was 1/20th of that in the Beaufort Sea and near Svalbard (Appendix I). Note that the estimated numbers in Table 4.8 represent the pinnipeds that would have been exposed had the animals not shown localized avoidance of the G. guns or the ship itself, and assume that all pinnipeds present were in the water. Many of the animals calculated (based on density) to be within the ≥180- or ≥190-dB zones would in fact move away before being exposed to sounds that strong. Also, some of those calculated to be in the ≥160- or ≥170 dB zones would be on the ice and not exposed to the underwater sounds.

NMFS commonly specifies that marine mammals exposed to pulsed sounds with received levels ≥160 dB re 1 µPa (rms) should be considered potentially disturbed. However, most pinnipeds (and delphinids) are unlikely to be disturbed appreciably by airgun sounds unless exposed to received levels ≥170 dB. These are not considered to be "all-or-nothing" criteria; some individual mammals may react strongly at lower received levels, but others are unlikely to react strongly unless levels are substantially above 160 or 170 dB.

Estimates of the densities of pinnipeds and cetaceans in marginal ice areas and in the polar pack ice are given in Appendices I.1–I.3, including approximate corrections for sightability biases. These corrected densities were used to estimate the number of marine mammals that were exposed to various received levels of G. gun sound, and thus potentially affected by seismic operations (Tables 4.8, 4.9).

(A) ≥160 dB (rms): We estimate that there would have been ~4003 exposures of ~3501 different individual seals (ringed, bearded, and spotted) to G. gun pulses with received levels ≥160 dB re 1 µPa (rms) during the survey if all seals were in the water but otherwise showed no avoidance (Table 4.8). The majority of the exposures (3804) would have been of ringed seals. Bearded seals and spotted seals are estimated to have been exposed to ≥160 dB on 198 occasions and 1 occasion, respectively.

TABLE 4.9. Estimated numbers of exposures, and estimated minimum numbers of individual cetaceans (bowheads, belugas, and narwhals) that might have been exposed, to sounds with received levels ≥160 dB, ≥170, ≥180 dB and ≥190 dB re 1 µPa (rms). These estimates assume that no cetaceans moved away from the approaching G. guns, which is unrealistic; actual numbers exposed, especially to the higher received levels, would have been lower. Estimates are based on "corrected" densities of cetaceans calculated from sighting and effort data in Moore et al. (2000). Also shown in boldface is the "harassment take" authorized by NMFS under the IHA.

Exposure level in dB re 1 µPa (rms)	Estimated numbers in pack ice margin areas		Estimated numbers in polar pack ice		Estimated total		**Requested take**
	Exposures	Individuals	Exposures	Individuals	Exposures	Individuals	
>160	146	127	18	2	164	129	**511**
>170	43	41	4	4	47	45	
>180	12	12	1	1	13	13	
>190	3	3	0	0	3	3	

(B) ≥170 dB (rms): On average, pinnipeds may be disturbed only if exposed to received levels of airgun sounds ≥170 dB re 1 µPa (rms). If so, then the estimated number of exposures would be ~29% of the corresponding estimates for ≥160 dB, based on the proportionally smaller areas exposed to ≥170 dB. Overall, there would have been ~1159 exposures of seals, involving ~1121 individuals, to seismic sounds ≥170 dB (Table 4.8).

(C) ≥180 dB (rms): Some pinnipeds no doubt were within the 180 dB radius (estimated as 500 to 2400 m, depending on water depth) around the operating G. guns but were missed by the observers even though all airgun operations were in daylight. Based on the densities of pinnipeds assumed in the EA and IHA applications, ~344 exposures of seals, involving ~337 individuals, would have been expected to occur within the 180 dB radius around the operating G. guns (Table 4.8). The latter estimate is far higher than the number of different individual seals (n = 29) that direct observations indicated were possibly exposed to ≥180 dB (Table G.3). The difference results (at least in part) from the fact that the estimates in Table 4.8 include any animals that

- avoided exposure to ≥180 dB by swimming away from the approaching seismic vessel, or
- were displaced from the track of the *Healy* by *Oden* when it earlier passed the same location, or
- were present but missed by visual observers because of the inevitable difficulties in sighting small seals in the water in the presence of ice, glare, wave action, etc. [Earlier studies have shown that the detectability of ringed seals in the water diminishes rapidly as distance increases beyond about 50 m—Harris et al. (2001); Moulton and Lawson (2002).]

(D) ≥190 dB (rms): MMOs watched for pinnipeds near the seismic vessel while it was conducting seismic operations as part of the monitoring and mitigation procedures. However, some pinnipeds within the 190 dB radius, which was nominally 100–150 m (Table 3.1), might not have been seen when they were at the surface. Based on the densities of pinnipeds assumed in the EA and IHA application, 104 exposures of 100 different pinnipeds to airgun sounds with received levels ≥190 dB (rms) would be

expected if there were no avoidance. However, because *Oden* likely displaced some pinnipeds from the trackline before *Healy* arrived, and because some additional pinnipeds likely swam away to avoid exposure to such strong seismic sounds, the actual number exposed was probably considerably lower than the above estimates.

Cetaceans.—Although no cetaceans were observed in the study area *per se* during the survey, it is possible that some cetaceans, undetected by the MMOs, were exposed to sound levels ≥160 dB. Based on densities derived from prior surveys in the eastern Alaskan Beaufort Sea in summer, we anticipated that as many as 511 cetaceans (bowheads, belugas, and narwhals) might be exposed to sound levels ≥160 dB re 1 μPa rms (LGL Ltd. 2005a,b). Table 4.9 summarizes the estimated numbers of cetacean exposures to ≥160 dB and other received sound levels for the area actually surveyed, which was smaller than assumed in the EA and IHA Application. The estimates for cetaceans exposed to ≥160 dB, based on densities from prior surveys, are 164 exposures and 129 individuals (maximum), or 32% of the number of exposures authorized by the IHA. Given the lack of any cetacean sightings, and the fact that many cetaceans avoid an approaching seismic vessel, the actual number of cetaceans exposed to ≥160 dB was, presumably, less than 129. It is extremely unlikely that 13 cetaceans were exposed to ≥180 dB. Most arctic cetaceans would be expected to avoid the approaching G. guns and vessel(s) before received levels of the pulses reached 180 dB (rms).

Summary and Conclusions

UAF's marine mammal monitoring program provided concentrated survey effort across the Arctic Ocean. Over 664 h (4768 km) of visual observations were made during the cruise; ~66% of the effort (in terms of hours) was during "useable" conditions, i.e., when visibility was appropriate for systematic surveys. A total of 102 individual marine mammals in 97 groups were observed during the survey. The analysis considered "useable" sightings, consisting of 89 individual marine mammals in 86 groups (Tables 4.1 and 4.2). Of these, 56 groups and 56 individuals (all seals) were in the water; the other seals and all the polar bears were on pack ice (Table ES.1). No injured marine mammals potentially associated with the operations were sighted.

Three different marine mammal species were identified within the study area. As expected, the ringed seal was the most abundant species, with 35 individuals identified. (Most of the 36 unidentified seals were undoubtedly ringed seals as well.) A large number of polar bears (15 sightings of 19 individuals) were seen from 23 to 26 Sept. in the ice margin north of Svalbard; less than an hour of seismic operations occurred during that time. All polar bears seen were on the ice and not exposed to underwater sounds. The third species identified was the bearded seal.

During the Arctic Ocean study, 62 groups of marine mammals involving 64 individuals were seen during seismic operations. Three power downs were initiated when three individual seals were determined to be in the water within the safety radius around the operating G. guns. Based on direct observations, one of those seals was likely exposed to underwater sound with levels ≥190 dB re 1 μPa (rms). For the other two seals, exposure to sound levels ≥190 dB was possible but unlikely.

Densities of marine mammals within the seismic study area were estimated based on a literature review of previous marine mammal surveys in the Arctic Ocean. Estimates of numbers of pinnipeds in areas exposed to seismic sounds are shown in Table 4.8. These estimates were based on the assumed densities and the areas that were ensonified to different sound levels during the Arctic Ocean survey. Also shown, for comparison, are the numbers of "harassment takes" to pinnipeds that were requested by L-DEO in the IHA application. The number of different individuals exposed to ≥160 dB re 1 μPa (rms) was estimated as ~73% of the pre-survey estimate. No cetaceans were detected by the MMOs during the seismic survey; however, some undetected cetaceans might have been exposed to sound levels ≥160 dB. Based on density estimates calculated from previous surveys, as many as 129 cetaceans (bowheads, belugas, and narwhals) might have received sound pulses with levels ≥160 dB during the Arctic Ocean seismic survey. That is likely an overestimate, given the fact that no cetaceans were observed in the area and that some cetaceans are expected to avoid an approaching vessel.

Overall, the seismic operations performed during the project are believed to have resulted in fewer animals being disturbed than estimated prior to the cruise. The observations confirmed that the marine mammal community across the Arctic Ocean is not diverse, with ringed seals and polar bears being the most abundant species.

Implementation of Terms of the IHA and Biological Opinion

UAF successfully implemented the mitigation and monitoring conditions stipulated in the IHA for the Arctic Ocean seismic survey, with some minor variations required to make the operations practicable. Provision 6(a)(4) of the IHA calls for a description of the implementation and effectiveness of the terms of the Biological Opinion (BO) issued by NMFS, and the mitigation measures specified in the IHA. Earlier sections of this report provide details on these matters, and the following summarizes the key points.

IHA's Mitigation and Monitoring Measures

(a) (a) ***Utilize MMOs***.—Four marine mammal observers were employed to monitor for mammals and implement the appropriate mitigation measures as necessary during the Arctic Ocean seismic cruise (Chapter 3). Three of the observers were trained biologists, each of whom had previous experience working as a vessel-based marine mammal observer during seismic programs conducted under IHAs (Appendix E). The fourth observer was an Inupiat, hired through the Barrow Arctic Science Consortium, who had decades of experience hunting in the Arctic (Appendix E). The observers monitored during all seismic operations and prior to all start ups for 30 min. There were no seismic operations at night, and thus no nighttime start-ups. Shifts were scheduled to overlap as much as possible and two observers were on watch ~46% of the time when visual watches were conducted (Chapter 3). Watches were scheduled to be no longer than 4 h in duration.

(b) ***Monitor Safety Radius During Ramp Ups***.—At least one observer monitored for marine mammals during every ramp up. Prior to and during ramp ups, the full extent of the safety radius—based on the 190 dB rms criterion for pinnipeds and 180 dB rms criterion for cetaceans—had to be visible. Seismic operations were not allowed to commence if a marine mammal was seen near, approaching, or within the safety radius.

Several days into the survey, it was realized that two MMOs would not always be available to observe for a full 30 min prior to starting the airguns, as initially required by the IHA. This occurred because of the following combination of factors: ***(1)*** MMOs were required to be on watch during all daylight hours of seismic operations, which continued 24 h/day for long stretches at a time in the upper latitudes. ***(2)*** Watches were limited to 4 h. ***(3)*** Watches with two observers were to be scheduled whenever possible. ***(4)*** The number of marine mammal observers (four) could not be increased. On 21 Aug., NMFS was informed by e-mail of the observers' occasional difficulty in complying with the "2 MMOs during ramp-up" requirement. On 22 Aug., the MMOs received an e-mail from NMFS acknowledging that the MMOs were making an effort to avoid the situation and that the infrequent occurrences would "not be a problem".

(c) ***Implement Ramp-Ups in Prescribed Manner***.—Ramp ups were implemented whenever operation of the 2 G. guns began. Both guns operated at half volume (2×125 in^3) for 5 min before the volume was increased to full (2×250 in^3 = 500 in^3). The original plan had been to operate 1 G. gun at full volume (250 in^3) for 5 min, and then to ramp up to 2 G. guns operating at full volume. The change was necessary to avoid damage to equipment (Chapter 3, Appendix E). The airgun operators communicated with the MMOs before initiating operations and before increasing the volume to full.

(d) ***Mitigation for Mammals Encountered during Seismic Operations***.—The MMOs initiated mitigation for marine mammals observed during seismic operations and assessed as likely to enter the safety zone. Mitigation options included course or speed alteration, which was impractical while in the ice pack, and power downs or shut downs (Chapter 3, Appendix E).

(e) ***Shut-down or Power-down***.—On three occasions during the Arctic Ocean seismic survey, a seal was observed approaching or within the safety zone and a power down was requested (Chapter 4, Appendix H). Two power downs and a shut down were implemented. The shut down was a more severe form of mitigation than was required; it occurred due to miscommunication between the MMOs and airgun operators (Chapter 4, Appendix H). The power downs consisted of reducing the volume of the G. guns from 500 in^3 to 250 in^3 and the shut down was a complete shut down of both G. guns. As required, after each power down, full-volume seismic operations did not resume until >15 min after the seal had last been seen within the safety radius. After the shut down, ramp up did not commence until the MMOs had not seen the seal within the safety radius for >15 min.

(f) ***Shut Downs for Right Whales or NE Atlantic Bowheads***.—No right whales or bowhead whales were seen during the survey. Hence, the special measures called for in the IHA for these two taxa did not need to be implemented.

(g) ***Re-Survey Areas via Small Boat or* Healy *if Opportunities Allow***.—A small boat was unavailable to the MMOs during the survey. Small-boat operations distant from the icebreaker would not have been safe in the circumstances of this project. Also, the *Healy* did not retrace its track. Thus, there were no opportunities to survey areas where seismic operations had occurred previously.

(h) ***Implement Acoustic Monitoring***.— Broadband sonobuoys were deployed periodically along the survey line during seismic operations. The sonobuoy transmissions were available to the observers via radio. The MMOs listened for marine mammal vocalizations during 33% of their periods of visual surveillance. No marine mammal calls were detected (Chapter 4).

(i) ***90-Day Report***.—The present report provides the specified information.

Terms and Conditions of Biological Opinion

Notice to NMFS re Any Changes or Deletions.—NMFS was informed when it was learned that two observers would not be available to watch for 30 min prior to some ramp ups (see above).

Re-Survey Areas via Small Boat or Healy if Opportunities Allow.—See above; there were no such opportunities.

Effectiveness of Mitigation.— To the best of our knowledge, the procedures recommended in the Biological Opinion and the IHA for the Arctic Ocean seismic survey were implemented successfully with the minor variations noted above. At least one marine mammal observer was on watch during all seismic operations. Whenever a marine mammal was observed approaching or within the safety radius, the appropriate mitigation measures were implemented. The only marine mammals observed during seismic operations were seals and polar bears; no cetaceans were observed during the seismic survey. No significant adverse effects on marine mammals were documented.

Report Results to NMFS Endangered Species Division.—A copy of this report will be provided to the Chief of the Endangered Species Division, as required.

Use Sonobuoys to Record Calls of Bowhead Whales.—see above.

5. ACKNOWLEDGEMENTS

The University of Alaska Fairbanks (UAF), the National Science Foundation (NSF), and the Norwegian Petroleum Directorate (NPD) provided the funding for the 2005 Arctic Ocean seismic survey and the associated marine mammal monitoring program. Logistical support for seismic operations was supplied by the University of Bergen (UiB). We thank Dr. Bernard Coakley of UAF, Dr. Yngve Kristoffersen of UiB, Renee Crain and Dr. Alexander Shor of NSF, and Dr. John Diebold of L-DEO for much assistance during planning and preparation for the cruise. Dr. Bernard Coakley coordinated the efforts to obtain and implement the incidental take authorization for the project, with additional input from Michael Rawson of L-DEO. BH plus William Koski, Michelle Gilders, and Meike Holst, all of LGL, were primarily responsible for preparing the IHA application and an associated Environmental Assessment (EA).

The crew on the seismic source vessel USCGC *Healy* was extremely supportive of the marine mammal monitoring and mitigation effort. In particular, we acknowledge the assistance of Captain Daniel K. Oliver, Jeffrey Jackson (Executive Officer), James Dalitch (Operations Officer), Don Snider (Chief Marine Science Technician), Jessica Noel (Marine Science Officer), and David Hassilev (Science Data Network Technician). We also thank Steve Roberts and Will Handley, of L-DEO, for their computer assistance.

We thank the seismic geophysics teams aboard the *Healy* led by Dr. Bernard Coakley (UAF), Dr. John Hopper (Texas A&M), and Dr. Yngve Kristoffersen (UiB). The geophysics team provided support and cooperation in obtaining data and implementing the marine mammal mitigation and monitoring program.

The vessel-based fieldwork was made possible by the dedicated participation of marine mammal observers Howie Goldstein (L-DEO), Alejandro Sayegh (Centro de Investigación de Cetáceos, Venezuela), and Jimmy Jones Olemaun (Barrow Arctic Science Consortium), along with the lead MMO, BH.

William Koski of LGL was principally responsible for developing the procedures to estimate numbers of marine mammals present and potentially affected. We also thank Mark Fitzgerald of LGL for helping to develop and implement those procedures, for assisting with processing and analyzing data, and for production of maps and figures. Dr. W. John Richardson, LGL's project director for this work, assisted at various stages during the planning, permitting, and fieldwork; he also reviewed and contributed to the draft report.

This work was conducted under an Incidental Harassment Authorization issued by the U.S. National Marine Fisheries Service (NMFS), Office of Protected Resources. We thank Ken Hollingshead, Jolie Harrison, and others of NMFS for processing the application, addressing the various agency and public comments, and working with UAF to define the expanded monitoring and mitigation requirements for this project. We also thank Dr. Bernard Coakley of UAF, Renee Crain and Dr. Alexander Shor of NSF, and Michael Rawson of L-DEO, for reviewing one or more of the initial application, EA and this report.

6. LITERATURE CITED

Amstrup, S. C. 1995. Movements, distribution, and population dynamics of polar bears in the Beaufort Sea. Ph.D. Dissertation. Univ. Alaska–Fairbanks, Fairbanks, AK. 299 p.

Angliss, R.P. and K.L. Lodge. 2004. Alaska marine mammal stock assessments, 2003. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-144. 230 p.

Barlow, J. 1999. Trackline detection probability for long-diving whales. p. 209-221 *In:* G.W. Garner, S.C. Amstrup, J.L. Laake, B.F.J. Manly, L.L. McDonald and D.G. Robertson (eds.), Marine mammal survey and assessment methods. A.A. Balkema, Rotterdam. 287 p.

Bengtson, J.L., P.L. Boveng, L.M. Hiruki-Raring, K.L. Laidre, C. Pungowiyi and M.A. Simpkins. 2000. Abundance and distribution of ringed seals (*Phoca hispida*) in the coastal Chukchi Sea. p. 149-160 *In* A.L. Lopez and D. P. DeMaster. Marine Mammal Protection Act and Endangered Species Act Implemention Program 1999. AFSC Processed Rep. 2000-11, Alaska Fish. Sci. Cent., Seattle, WA.

Bjørge, A., R.L. Brownell Jr., W.F. Perrin and G.P. Donovan (eds). 1991 *Delphinapterus leucas.* p. 12-24 *In*: Significant direct and incidental catches of small cetaceans. A report by the **Sci. Comm. Int. Whal. Comm**.

Buckland, S.T., D. Bloch, K.L. Cattanach, T. Gunnlaugsson, K. Hoydal, S. Lens and J. Sigurjónsson. 1993. Distribution and abundance of long-finned pilot whales in the North Atlantic, estimated from NASS-1987 and NASS-89 data. **Rep. Int. Whal. Comm. Spec. Iss.** 14:33-50.

Burgess, W.C. and C.R. Greene, Jr. 1999. Physical acoustics measurements. p. 3-1 to 3-63 *In*: W.J. Richardson (ed.), Marine mammal and acoustical monitoring of Western Geophysical's open-water seismic program in the Alaskan Beaufort Sea, 1998. LGL Rep. TA22303. Rep. from LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for Western Geophysical, Houston, TX, and U.S. Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD. 390 p.

Burns, J.J. 1981. Bearded seal *Erignathus barbatus* Erxleben, 1777. p. 145-170 *In* S.H. Ridgway and R.J. Harrison (eds.), Handbook of Marine Mammals. Vol. 2. Seals. Academic Press, New York.

CAFF n.d. Arctic Flora and Fauna: Recommendations for Conservation. Prepared by the Conservation of Arctic Flora and Fauna (CAFF) Working Group. Working Group of the Arctic Council. CAFF International Secretariat, Iceland.

Caldwell, J. and W. Dragoset. 2000. A brief overview of seismic air-gun arrays. **The Leading Edge** 2000(8, Aug.): 898-902.

Cattanach, K.L., J. Sigurjónsson, S.T. Buckland and T. Gunnlaugsson. 1993. Sei whale abundance in the North Atlantic, estimated from NASS-87 and NASS-89 data. **Rep. Int. Whal. Comm.** 43:315-321.

Christensen, I., T. Haug and N. Øien. 1992. Seasonal distribution, exploitation and present abundance of stocks of large baleen whales (Mysticeti) and sperm whales (*Physeter macrocephalus*) in Norwegian and adjacent waters. **ICES J. Mar. Sci**. 49(3):341-355.

Cipriano, F. 2002. Atlantic white-sided dolphin. p. 49-51 *In*: W.F. Perrin, B. Würsig and J.G.M. Thewissen (eds.), Encyclopedia of marine mammals. Academic Press, San Diego, CA.

Clark, J.T. and S.E. Moore. 2002. A note on observations of gray whales in the southern Chukchi and northern Bering Seas, August-November, 1980-1989. **J. Cetac. Res. Manage**. 4(3):283-288.

DFO Canada. 2004. North Atlantic Right Whale. Fisheries and Oceans Canada. Available at http://www.mar.dfo-mpo.gc.ca/masaro/english/Species_Info/Right_Whale.html

Finneran, J.J., C.E. Schlundt, R. Dear, D.A. Carder and S.H. Ridgway. 2002. Temporary shift in masked hearing thresholds in odontocetes after exposure to single underwater impulses from a seismic watergun. **J. Acoust. Soc. Am.** 111(6):2929-2940.

George, J.C., J. Zeh, R. Suydam and C. Clark. 2004. Abundance and population trend (1978-2001) of Western Arctic bowhead whales surveyed near Barow, Alaska. **Mar. Mamm. Sci.** 20(4):755-773.

Gordon, J., D. Gillespie, J. Potter, A. Frantzis, M.P. Simmonds, R. Swift and D. Thompson. 2004. A review of the effects of seismic surveys on marine mammals. **Mar. Technol. Soc. J.** 37(4):16-34.

Greene, C.R., Jr. 1997. Physical acoustics measurements. (Chap. 3, 63 p.) *In*: W.J. Richardson (ed.), 1997. Northstar Marine Mammal Marine Monitoring Program, 1996. Marine mammal and acoustical monitoring of a seismic program in the Alaskan Beaufort Sea. Rep. TA2121-2. Rep. from LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for BP Explor. (Alaska) Inc., Anchorage, AK, and U.S. Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD. 245 p.

Greene, C.R., Jr. and W.J. Richardson. 1988. Characteristics of marine seismic survey sounds in the Beaufort Sea. **J. Acoust. Soc. Am.** 83(6):2246-2254.

Greene, C.R., Jr., R. Norman and J.S. Hanna. 1998. Physical acoustics measurements. p. 3-1 to 3-64 *In:* W.J. Richardson (ed.), Marine mammal and acoustical monitoring of BP Exploration (Alaska)'s open-water seismic program in the Alaskan Beaufort Sea, 1997. LGL Rep. TA2150-3. Rep. from LGL Ltd., King City, Ont., and Greeneridge Sciences Inc., Santa Barbara, CA, for BP Explor. (Alaska) Inc., Anchorage, AK, and U.S. Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD. 318 p.

Gunnlaugsson, T. and J. Sigurjónsson. 1990. NASS-87: estimation of whale abundance based on observations made onboard Icelandic and Faroese survey vessels. **Rep. Int. Whal. Comm.** 40:571-580.

Haley, B., and W.R. Koski. 2004. Marine mammal monitoring during Lamont-Doherty Earth Observatory's seismic program in the Northwest Atlantic Ocean, July–August 2004. LGL Rep. TA2822-27. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 80 p.

Hammond, P., H. Benke, P. Berggren, A. Collet, M.P. Heide-Jørgensen, S. Heimlich-Boran, M. Leopold and N. Øien. 2001. The distribution and abundance of harbour porpoises and other small cetaceans in the North Sea and adjacent waters. Copenhagen, Denmark. ICES. 20 p.

Hammond, P.S., P. Berggren, H. Benke, D. L. Borchers, A. Collet, M. P. Heide-Jørgensen, S. Heimlich, A. R. Hiby, M. F. Leopold and N. Øien. 2002. Abundance of harbour porpoise and other cetaceans in the North Sea and adjacent waters. **J. Appl. Ecol.** 39(2):361-376.

Harris, R.E., G.W. Miller and W.J. Richardson. 2001. Seal responses to airgun sounds during summer seismic surveys in the Alaskan Beaufort Sea. **Mar. Mamm. Sci.** 17(4):795-812.

Harwood, L., S. Innes, P. Norton and M. Kingsley. 1996. Distribution and abundance of beluga whales in the Mackenzie estuary, southeast Beaufort Sea, and the west Amundsen Gulf during late July 1992. **Can. J. Fish. Aquatic Sci.** 53(10):2262-2273.

Heide-Jørgensen, M.P., N. Hammeken, R. Dietz, J. Orr and P.R. Richard. 2002. Surfacing times and dive rates for narwhals (*Monodon monoceros*) and belugas (*Delphinapterus leucas*). **Arctic** 54(3):284-298.

Henriksen, G., I. Gjertz and A. Kondrakov. 1997. A review of the distribution and abundance of harbor seals, *Phoca vitulina*, on Svalbard, Norway, and in the Barents Sea. **Mar. Mamm. Sci**. 13(1):157-163

Holbrook, W.S., P. Paramo, S. Pearse and R.W. Schmitt. 2003. Thermohaline fine structure in an oceanographic front from seismic reflection profiling. **Science** 301(5634):821-824.

Holst, M. 2004. Marine mammal monitoring during Lamont-Doherty Earth Observatory's TAG seismic study in the mid-Atlantic Ocean, October-November 2003. LGL Rep. TA2822-21. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory, Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 42 p.

Holst, M., M.A. Smultea, W.R. Koski, and B. Haley. 2005a. Marine mammal and sea turtle monitoring during Lamont-Doherty Earth Observatory's marine seismic program in the Eastern Tropical Pacific Ocean off Central America, November-December 2004. LGL Rep. TA2822-30. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 125 p.

Holst, M., M.A. Smultea, W.R. Koski, and B. Haley. 2005b. Marine mammal and sea turtle monitoring during Lamont-Doherty Earth Observatory's marine seismic program off the Northern Yucatan Peninsula in the Southern Gulf of Mexico, January-February 2005. LGL Rep. TA2822-31. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 96 p.

Ireland, D., M. Holst, and W.R. Koski. 2005. Marine mammal monitoring during Lamont-Doherty Earth Observatory's seismic program off the Aleutian Islands, Alaska, July–August 2005. LGL Rep. TA4089-3. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 83 p.

IUCN (The World Conservation Union). 2002. IUCN Red List of Threatened Species. http://www.iucn.org/themes/ssc/redlist2002/redlistlaunch.htm

IWC (International Whaling Commission). 2000. Report of the Scientific Committee from its Annual Meeting 3-15 May 1999 in Grenada. **J. Cetac. Res. Manage.** 2 (Suppl).

Keller, A.C. and L.R. Gerber 2004. Monitoring the Endangered Species Act: revisiting the eastern North Pacific gray whale. **Endangered Species Update** 21(3):87-92.

Kingsley, M.C.S. 1986. Distribution and abundance of seals in the Beaufort Sea, Amundsen Gulf, and Prince Albert Sound, 1984. Environ. Studies Revolving Funds Rep. No. 25. 16 p.

Koski, W.R. and R.A. Davis. 1994. Distribution and numbers of narwhals (*Monodon monoceros*) in Baffin Bay and Davis Strait. **Medd. Grønl., Biosci.** 39:15-40.

Koski, W.R., D.H. Thomson and W.J. Richardson. 1998. Descriptions of Marine Mammal Populations. p. 1-182 plus Appendices *In:* Point Mugu Sea Range Marine Mammal Technical Report. Rep. from LGL Ltd., King City, Ont., for Naval Air Warfare Center, Weapons Div., Point Mugu, CA, and Southwest Div. Naval Facilities Engin. Command, San Diego, CA. 322 p.

LGL Ltd. 2005a. Request by the University of Alaska Fairbanks for an Incidental Harassment Authorization to allow the incidental take of marine mammals during a marine geophysical survey across the Arctic Ocean, August-September 2005. LGL Rep. TA4122-2. Rep. from LGL Alaska Res. Assoc. Inc., Anchorage, AK, for Univ. Alaska Fairbanks, Fairbanks, AK, and Nat. Mar. Fish. Serv., Silver Spring, MD. 84 p

LGL Ltd. 2005b. Environmental assessment of a marine geophysical survey across the Arctic Ocean, August-September 2005. LGL Rep. TA4122-1. Rep. from LGL Alaska Res. Assoc. Inc., Anchorage, AK, for Univ. Alaska Fairbanks, Fairbanks, AK, and Nat. Sci. Found., Arlington, VA. 98 p.

MacLean, S.A. and B. Haley. 2004. Marine mammal monitoring during Lamont-Doherty Earth Observatory's seismic study in the Støregga Slide area of the Norwegian Sea, August - September 2003. LGL Rep. TA2822-20. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory, Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 59 p.

MacLean, S.A. and W.R. Koski. 2005. Marine mammal monitoring during Lamont-Doherty Earth Observatory's seismic program in the Gulf of Alaska, August–September 2004. LGL Rep. TA2822-28. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 102 p.

Martin, A.R. and T.G. Smith. 1992. Deep diving in wild, free-ranging beluga whales, *Delphinapterus leucas*. **Can. J. Fish. Aquatic Sci.** 49:462-466.

McCauley, R.D., M.-N. Jenner, C. Jenner, K.A. McCabe and J. Murdoch. 1998. The response of humpback whales (*Megaptera novangliae*) to offshore seismic survey noise: preliminary results of observations about a working seismic vessel and experimental exposures. **APPEA (Austral. Petrol. Product. Explor. Assoc.) Journal** 38:692-707.

McCauley, R.D., J. Fewtrell, A.J. Duncan, C. Jenner, M.-N. Jenner, J.D. Penrose, R.I.T. Prince, A. Adhitya, J. Murdoch, and K. McCabe. 2000. Marine seismic surveys: Analysis of airgun signals; and effects of air gun exposure on humpback whales, sea turtles, fishes and squid. Rep. from Centre for Marine Science and Technology, Curtin Univ., Perth, W.A., for Austral. Petrol. Prod. Assoc., Sydney, N.S.W. 188 p.

Miller, G.W., V.D. Moulton, R.A. Davis, M. Holst, P. Millman, A. MacGillivray and D. Hannay. 2005. Monitoring seismic effects on marine mammals--southeastern Beaufort Sea, 2001-2002. p. 511-542 *In:* S.L. Armsworthy, P.J. Cranford and K. Lee (eds.), Offshore oil and gas environmental effects monitoring/Approaches and technologies. Battelle Press, Columbus, OH.

Moore, S.E., D.P. DeMaster and P.K. Dayton. 2000. Cetacean habitat selection in the Alaskan Arctic during summer and autumn. **Arctic** 53(4):432-447.

Moulton, V.D. and J.W. Lawson. 2002. Seals, 2001. p. 3-1 to 3-48 *In:* W.J. Richardson and J.W. Lawson (eds.), Marine mammal monitoring of WesternGeco's open-water seismic program in the Alaskan Beaufort Sea, 2001. LGL Rep. TA2564-4. Rep. from LGL Ltd., King City, Ont., for WesternGeco LLC, Anchorage, AK; BP Explor. (Alaska) Inc., Anchorage, AK; and Nat. Mar. Fish. Serv., Anchorage, AK, and Silver Spring, MD. 95 p.

Moulton, V.D. and M.T. Williams. 2003. Incidental sightings of polar bears during monitoring activities for BP's Northstar oil development, Alaskan Beaufort Sea, 2002. Rep. from LGL Ltd., King City, Ont., for BP Explor. (Alaska) Inc. and USFWS Office of Mar. Mamm. Manage, Anchorage, AK.

NAMMCO (North Atlantic Marine Mammal Commission). 2001. NAMMCO Annual Report 2001. North Atlantic Marine Mammal Commission, Tromsø, Norway. 335 p.

NAMMCO (North Atlantic Marine Mammal Commission). 1995. Report of the third meeting of the Scientific Committee. p. 71-127 *In*: NAMMCO Annual Report 1995, NAMMCO, Tromsø.

NMFS. 1995. Small takes of marine mammals incidental to specified activities; offshore seismic activities in southern California. **Fed. Regist.** 60(200, 17 Oct.):53753-53760.

NMFS. 2000. Small takes of marine mammals incidental to specified activities; marine seismic-reflection data collection in southern California/Notice of receipt of application. **Fed. Regist.** 65(60, 28 Mar.):16374-16379.

NMFS. 2005a. Small takes of marine mammals incidental to specified activities; marine geophysical survey across the Arctic Ocean/Notice of receipt of application… **Fed. Regist.** 70(89, 10 May.):24539-24553.

NMFS. 2005b. Small takes of marine mammals incidental to specified activities; marine geophysical survey across the Arctic Ocean/Notice of issuance of an incidental take authorization. **Fed. Regist.** 70(156, 15 Aug.): 47792-47809.

Øien, N. 1990. Sightings surveys in the Northeast Atlantic in July 1988: distribution and abundance of cetaceans. **Rep. Int. Whal. Comm.** 40:499-511.

Reeves, R.R., C. Smeenk, C.C. Kinze, R.L. Brownell, Jr. and J. Lien. 1999. White-beaked dolphin *Lagenorhynchus albirostris* Gray, 1846. p. 1-30 *In*: S.H. Ridgway and R. Harrison (eds.), Handbook of Marine Mammals Vol. 6: The Second Book of Dolphins and the Porpoises. 486 p.

Reyes, J.C. 1991. The conservation of small cetaceans: a review. Report prepared for the Secretariat of the Convention on the Conservation of Migratory Species of Wild Animals. UNEP/CMS Secretariat, Bonn.

Richardson, W.J., C.R. Greene, Jr., C.I. Malme and D.H. Thomson. 1995. Marine mammals and noise. Academic Press, San Diego. 576 p.

Small, R.J. and D.P. DeMaster. 1995. Alaska marine mammal stock assessments 1995. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-57, 93 pp.

Smultea, M.A. and M. Holst. 2003. Marine mammal monitoring during Lamont-Doherty Earth Observatory's seismic study in the Hess Deep area of the Eastern Equatorial Tropical Pacific, July 2003. LGL Rep. TA2822-16. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory, Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 68 p.

Smultea, M.A., M. Holst, et al. 2003. Marine mammal monitoring during Lamont-Doherty Earth Observatory's acoustic calibration study in the northern Gulf of Mexico, 2003. LGL Rep. TA2822-12. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory, Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD.

Smultea, M.A., M. Holst, W.R. Koski and S. Stoltz. 2004. Marine mammal monitoring during Lamont-Doherty Earth Observatory's seismic program in the Southeast Caribbean Sea and adjacent Atlantic Ocean, April–June 2004. LGL Rep. TA2822-26. Rep. From LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 106 p.

Smultea, M.A., W.R. Koski and T.J. Norris. 2005. Marine mammal monitoring during Lamont-Doherty Earth Observatory's marine seismic study of the Blanco Fracture Zone in the Northeastern Pacific Ocean, October-November 2004. LGL Rep. TA2822-29. Rep. From LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observatory of Columbia Univ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. 89 p.

Stirling, I., M. Kingsley and W. Calvert. 1982. The distribution and abundance of seals in the eastern Beaufort Sea, 1974-79. **Can. Wildl. Serv. Occas. Pap.** 47. 25 p.

Stone, C.J. 2003. The effects of seismic activity on marine mammals in UK waters 1998-2000. JNCC Report 323. Joint Nature Conservancy, Aberdeen , Scotland. 43 p.

Thomas, T.A., W.R. Koski and W.J. Richardson. 2002. Correction factors to calculate bowhead whale numbers from aerial surveys of the Beaufort Sea. p. 15-1 to 15-28 (Chap. 15) *In*: W.J. Richardson and D.H. Thomson (eds.), Bowhead whale feeding in the eastern Alaskan Beaufort Sea: update of scientific and traditional information, vol. 1. OCS Study MMS 2002-012; LGL Rep. TA2196-7. Rep. from LGL Ltd., King City, Ont., for U.S. Minerals Manage. Serv., Anchorage, AK, and Herndon, VA. 420 p.

Thompson, D., M. Sjöberg, E.B. Bryant, P. Lovell, and A. Bjørge. 1998. Behavioural and physiological responses of harbour (*Phoca vitulina*) and grey (*Halichoerus grypus*) seals to seismic surveys. p. 134 *In:* World Marine Mammal Science Conf. Abstract volume, Monaco. 160 p.

Tolstoy, M., J. Diebold, S. Webb, D. Bohnenstiehl and E. Chapp. 2004a. Acoustic calibration measurements. Chapter 3 *In:* W.J. Richardson (ed.), Marine mammal and acoustic monitoring during Lamont-Doherty Earth Observatory's acoustic calibration study in the northern Gulf of Mexico, 2003. Revised ed. Rep. from LGL Ltd., King City, Ont., for Lamont-Doherty Earth Observ., Palisades, NY, and Nat. Mar. Fish. Serv., Silver Spring, MD. (Advance copy).

Tolstoy, M., J.B. Diebold, S.C. Webb, D.R. Bohenstiehl, E. Chapp, R.C. Holmes and M. Rawson. 2004b. Broad-band calibration of R/V *Ewing* seismic sources. **Geophys. Res. Lett.** 31: L14310.

UNEP-WCMC. 2004. UNEP-WCMC species database: CITES-listed species. Available at http://www.unep-wcmc.org/index.html?http://sea.unep-wcmc.org/isdb/CITES/Taxonomy/tax-gs-search1.cfm?displaylanguage=eng&source=animals~main

USDI/MMS. 1996. Beaufort Sea Planning Area oil and gas lease sale 144/Final Environmental Impact Statement. OCS EIS/EA MMS 96-0012. U.S. Minerals Manage. Serv., Alaska OCS Reg., Anchorage, AK. Two volumes. Var. pag.

USFWS. 2000. Pacific walrus (*Odobenus rosmarus divergens*): Alaska Stock. p. 185-190 *In*: R.C. Ferrero, D.P. DeMaster, P.S. Hill, M.M. Muto, and A.L. Lopez (eds.) Alaska marine mammal stock assessments, 2000. NOAA Tech. Memo. NMFS-AFSC-119. U.S. Dep. Comm. NOAA, NMFS, Alaska Fisheries Science Center.

Whitehead, H. 2002. Estimates of the current global population size and historical trajectory for sperm whales. **Mar. Ecol. Prog. Ser.** 242:295-304.

APPENDIX A:[1]

Incidental Harassment Authorization Issued to UAF for a Marine Geophysical Survey across the Arctic Ocean

DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL MARINE FISHERIES SERVICE

Incidental Harassment Authorization

The University of Alaska Fairbanks, 903 Koyukuk Drive, P.O. Box 757320 is hereby authorized under section 101(a)(5)(D) of the Marine Mammal Protection Act (16 U.S.C. 1371(a)(5)(D)) and 50 CFR 216.107, to harass a small number of marine mammals incidental to a seismic surveys conducted by the U.S. Coast Guard Cutter *Healy* across the Arctic Ocean, August-September, 2005:

1. This Authorization is valid from August 5, 2005 through August 4, 2006.

2. This Authorization is valid only for the *Healy's* seismic survey across the Arctic Ocean, from August-September, 2005.

3. (a) The taking, by incidental harassment only, is limited to no more than the following numbers of each species:

Atlantic white-beaked dolphin (*Lagenorhynchus albirostris*) – 10
Atlantic white-sided dolphin (*Lagenorhynchus acutus*) – 10
Killer whale (*Orcinus orca*) – 5
Long-finned pilot whale (*Globicephala melas*) - 10
Northern bottlenose whale (*Hyperoodon ampullatus*) – 5
Beluga whale (*Delphinapterus leucas*) – 117
Narwhal (*Monodon monoceros*) – 156
Harbor Porpoise (*Phocoena phocoena*) – 5
Western Arctic Bowhead whale (*Balaena mysticetus*) – 238
Gray Whale (*Eschrich[ti]us robustus*) – 20
Minke whale (*Balaenoptera acutorostrata*) – 5
Bearded seal (*Erignathus barbatus*) – 111
Harbor seal (*Phocina vitulina richardsi*) – 2
Spotted seal (*Phoca largha*) – 5
Ringed seal (*Phoca [hispida]*) – 4536
Hooded seal (*Cystophora cristata*) – 7
Harp seal (*Phoca groenlandica*) - 21

[1] This is a verbatim copy (retyped) of the IHA, aside from corrections to typos shown as *[…]*.

The taking by serious injury or death of any of these species, or the taking by harassment, injury or death of any other species of marine mammal, is prohibited and may result in the modification, suspension or revocation of this Authorization.

(b) The taking of any marine mammal in a manner prohibited under this Authorization must be reported immediately to the Alaska Regional Office, Anchorage, National Marine Fisheries Service (NMFS), at (907) 271-5006, and the Office of Protected Resources (NMFS), at (301) 713-2289.

4. The holder of this Authorization is required to cooperate with NMFS and any other Federal, state or local agency monitoring the impacts of the activity on marine mammals

5. <u>Mitigation and Monitoring</u>

The holder of this Authorization is required to:

(a) Utilize four NMFS-approved marine mammal observers (MMOs) to monitor marine mammals near the seismic source vessel during all daytime hours and during any start ups of the airgun(s) at night. Two observers will simultaneously be on duty whenever possible, and as described in (b), below. Shifts will last no longer than 4 hours at a time.

(b) Visually observe the entire extent of the safety radius (190 dB for pinnipeds, 180 dB for cetaceans) using two marine mammal observers, at least 30 minutes prior to starting the airguns. If for any reason the entire radius cannot be seen for the entire 30 minutes (i.e. rough seas, fog, darkness), or if marine mammals are near, approaching, or in the safety radius, the airguns may not be started up. If one airgun is already running, UAF may start the second gun without observing the entire safety radius for 30 minutes prior, provided no marine mammals are known to be near the safety radius.

(c) Implement a “ramp-up” procedure when starting up the two-gun array, which means start up one gun, and wait five minutes before starting up the other.

(d) Alter speed or course during seismic operations if a marine mammal, based on its position and relative motion, appears likely to enter the safety zone. If speed or course alteration is not safe or practical, or if after alteration the marine mammal still appears likely to enter the safety zone, further mitigation measures, such as airgun shut-down, will be taken.

(e) Shut-down or Power-down the airguns if a marine mammal approaches or enters the safety radius. A shut-down means all operating airguns are shut down. When the two-gun array is running, a power-down is possible, which means shutting down one airgun and reducing the safety radius. Following a power-down, if the marine mammal approaches the smaller safety radius, the airguns must then be completely shut down. Airgun activity will not resume until the marine mammal has cleared the safety radius, which means it was visually observed to have left the safety radius, or has not been seen within the radius for 15 min (small odontocetes and pinnipeds) or 30 min (mysticetes and large odontocetes, including sperm and beaked whales).

(f) Shut down all airguns immediately in the unlikely event a right whale is sighted, or a bowhead is sighted in the Svalbard *[area]*, regardless of the distance of the whale from the airgun(s).

Airguns may not be started again until the whale is seen to have moved away from the Healy and has been completely out of the visual range of the observers for at least 30 minutes.

(g) Using a small boat or the *Healy*, take every opportunity to survey areas that were seismically surveyed to record the behavior of any marine mammals that are present and observable and record any occurrences of dead or injured animals.

(h) Implement passive acoustic monitoring of marine mammals, utilizing the sonob*[uo]*ys, to gather information on the presence/absence of marine mammals in the higher Arctic latitudes.

6. Reporting

The holder of this authorization is required to:

(a) Submit a report on all activities and monitoring results to the Office of Protected Resources, NMFS, and the Alaska Regional Administrator, NMFS, within 90 days of the completion of the *Healy's* cruise. This report must contain and summarize the following information:

(1) Dates of, times of, locations of, and weather during (including Beaufort Sea State) all seismic operations;

(2) Species, number, location, and behavior of any marine mammals, as well as associated seismic activity, observed throughout all monitoring activities (both visually and through passive acoustic monitoring).

(3) An estimate of the number (by species) of marine mammals that may have been harassed by the seismic activity with a discussion of the specific behaviors associated with the probable takes.

(4) A description of the implementation and effectiveness of the*[]* (a) terms and conditions of the biological opinion (BO) (attached), and (b) mitigation measures of the IHA. For the biological opinion, the report will confirm the implementation of each term and condition and describe the effectiveness, as well as any conservation measures, for minimizing the adverse effects of the action on listed whales.

(b) In the unanticipated event that any cases of marine mammal injury or mortality are judged to result from these activities, UAF will report the incident to NMFS and the local stranding network immediately.

7. A copy of this Authorization must be in the possession of the operator of the vessel operating under the authority of this Incidental Harassment Authorization.

APPENDIX B:

Informal Consultation letter from USFWS to NSF for a Marine Geophysical Survey across the Arctic Ocean

United States Department of the Interior

FISH AND WILDLIFE SERVICE
1011 E. Tudor Rd.
Anchorage, Alaska 99503-6199

IN REPLY REFER TO:

AFES/MMM

MAY 20 2005

Ms. Polly Penhale
Environmental Officer
National Science Foundation
Office of Polar Programs
4201 Wilson Boulevard
Arlington, Virginia 22230

Dear Ms. Penhale:

This responds to your May 6, 2005, request for informal consultation regarding potential interaction between polar bears and Pacific walrus with the USCGC *Healy* while conducting scientific research during a National Science Foundation (NSF)-sponsored seismic survey. Seismic activity will begin north of Barrow, Alaska and transit over the North Pole to the vicinity of Svalbard Islands from August 9 through September 25, 2003.

During this time, the majority of polar bears will most likely be encountered offshore in the mixed-year and multi-year pack ice, generally in the area near leads or polynyas or near the leading edge of the pack ice. Bears may also be encountered in open water in advance of the pack ice.

In August and September, Pacific walrus are widely distributed across the continental shelf waters of the Chukchi Sea. The distribution of walrus herds during the proposed operational window will depend in part on prevailing ice conditions. Large concentrations of walruses are most likely to be found within a 50 mile zone of the leading edge of the pack ice, although small numbers may also be encountered foraging in open water.

The U.S. Fish and Wildlife Service (USFWS) believes that any encounters with Pacific walrus or polar bears will be limited and result in short-term localized changes in behavior near the vessel. Encounters with polar bears or walrus may lead to unintentional, or incidental "takes" of these animals. The term ''take,'' as defined by the Marine Mammal protection Act (MMPA), means to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal. Harassment, as defined by the MMPA, means "any act of pursuit, torment, or annoyance which (i) has the potential to injure a marine mammal or marine mammal stock in the wild" (Level A harassment); "or (ii) has the potential to disturb a marine mammal or marine mammal stock in the wild

Ms. Polly Penhale 2

by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering" (Level B harassment).

Although, the USFWS has no mechanism to issue an incidental take authorization to NSF for this project, the USFWS believes that protection measures for marine mammals described in the EA are also appropriate safeguards for Pacific walrus and polar bears to limit human/animal interactions. Polar bears could be attracted to the *Healy* or the open water created by the *Healy*. NSF and the *Healy* can limit encounters of polar bears and walrus by being observant of approaching animals (i.e., the use of marine mammal observer program, which is already in place) and breaking off interactions, if practicable, by allowing the animals to continue their travel. USFWS biologists are also available for consultation if questions or concerns about arise regarding polar bears or walrus during this survey at the phone numbers listed below.

If a polar bear interaction escalates into a life threatening situation, Section 101(c) of the MMPA allows, without specific authorization, the take (including lethal take) of a polar bear if such taking is imminently necessary in self-defense or to save the life of a person in immediate danger, and such taking is reported to the USFWS, Marine Mammal Management Office within 48 hours.

In addition, we are interested in human/polar bear interactions and polar bear and walrus observations throughout the range of both animals. For example, in 2004 there were several reports of walrus calves swimming alone north of Barrow. Our office would appreciate any details from similar observations including locational fixes and behavioral observations of these animals. Hence, we are including standardized Polar Bear and Walrus Sighting Report forms for you to use prior to and during the survey. The use of the forms is voluntary, but any information describing polar bear or walrus sightings are beneficial to us for monitoring these populations.

If you have further questions, please contact me at the Marine Mammals Management Office at (907) 786-3800 or 786-3810 (direct).

Sincerely,

Craig Perham
Incidental Take Coordinator
Marine Mammals Management

Enclosures

APPENDIX C:
DEVELOPMENT AND IMPLEMENTATION OF SAFETY RADII

This appendix provides additional background information on the development and implementation of safety radii as relevant to the UAF seismic study discussed in this report. Additional information on L-DEO's calibration study conducted with various configurations of airgun arrays is also provided. Further information on these topics can be found in Smultea and Holst (2003), Tolstoy (2004a,b), and the project IHA application and EA (LGL 2005a,b).

It is not known whether exposure to a sequence of strong pulses of low-frequency underwater sound from marine seismic exploration actually can cause hearing impairment or non-auditory injuries in marine mammals (Richardson et al. 1995:372*ff*; Finneran et al. 2002). There has been considerable speculation about the potential for injury to marine mammals, based primarily on what is known about hearing impairment to humans and other terrestrial mammals exposed to impulsive low-frequency airborne sounds (e.g., artillery noise). The 180-dB criterion for cetaceans was established by NMFS (1995) based on those considerations, before any data were available on temporary threshold shift (TTS) in marine mammals. NMFS (1995, 2000) concluded that there are unlikely to be any physically-injurious effects on cetaceans exposed to received levels of seismic pulses up to 180 dB re 1 μPa root-mean-square (rms). The corresponding NMFS criterion for pinnipeds is 190 dB re 1 μPa (rms).

Finneran et al. (2002) have found that the onset of mild TTS in a beluga whale (odontocete) exposed to a single watergun pulse occurred at a received level of 226 dB re 1 μPa pk-pk and a total energy flux density of 186 dB re 1 $\mu Pa^2 \cdot s$. The corresponding rms value for TTS onset upon exposure to a single watergun pulse would be intermediate between these values. It is assumed (though data are lacking) that TTS onset would occur at lower received pressure levels if the animals received a series of pulses. However, no specific results confirming this are available yet. On the other hand, the levels necessary to cause injury would exceed, by an uncertain degree, the levels eliciting TTS onset.

The above-mentioned 180 dB re 1 μPa level is measured on an rms basis. The rms pressure is an average over the duration of the seismic pulse (Greene 1997; Greene et al. 1998). This is the measure commonly used in recent studies of marine mammal reactions to airgun sounds. The rms level of a seismic pulse is typically about 10 dB less than its peak level (Greene 1997; McCauley et al. 1998, 2000). Rms level is affected by duration of the received pulse, which depends on propagation effects between the source and the receiving animal. The greater the temporal dispersion of (i.e., the longer) the received pulse, the lower the expected rms level. Biological effects probably are more closely related to energy content of the received pulse than to its rms pressure, but we consider rms pressure because current NMFS criteria are based on that method.

Radii within which received levels were expected to diminish to various values relevant to NMFS criteria mentioned above were estimated by L-DEO for UAF based on a combination of acoustic modeling and empirical measurements. Empirical data were obtained by Tolstoy et al. (2004a,b) for sounds from two 105 in^3 GI (generator injector) guns, a 20-airgun array, and various intermediate-sized airgun arrays. (The 2 GI guns used in the calibration study had a lower total volume [210 in^3] than the 2 G. guns [volume 500 in^3] used in the Aug.-Sept. 2005 Arctic Ocean study.) The empirical data were collected in the Gulf of Mexico from 27 May to 3 June 2003, with separate measurements in deep and shallow water (Tolstoy et al. 2004a,b).

The rms received levels in the near field around various airgun configurations used by L-DEO have been predicted based on an L-DEO model. Figure C.1 shows the predicted sound field for 2 G. guns with a combined volume of 500 in^3, on which the safety radii for the Arctic Ocean study were based. The sound fields shown in Figure C.1 pertain primarily to deep water, and the model does not allow for bottom interactions.

For mitigation purposes during seismic studies, three strata of water depth are distinguished: shallow (<100 m), intermediate (100–1000 m), and deep (>1000 m). The calibration study showed that sounds from L-DEO's larger airgun sources (i.e., 6–20 airguns) operating in deep water tended to have lower received levels than estimated by the model. In other words, the model tends to overestimate the actual distances at various sound levels in deep water (Tolstoy et al. 2004a,b). Conversely, in shallow water, the model substantially underestimates the actual measured radii for various source configurations ranging from 2 to 20 airguns. More specifically, the primary conclusions of L-DEO's calibration study relevant to this and other recent projects are summarized below, along with comments on how those conclusions were used in estimating radii for the two G. guns used in the *Healy* study:

- Empirical measurements were made in the Gulf of Mexico for two 105 in^3 GI guns operating in shallow water (<100 m). Those data showed that modeled values underestimated actual levels in shallow water at corresponding distances of ~0.5 to 1.5 km by a factor of ~3× (Tolstoy et al. 2004b). Sound level measurements for the two 105 in^3 GI guns were not available for distances <0.5 km from the source. The radii estimated here for two 250 in^3 G. guns operating in shallow waters are derived from L-DEO's deep water estimates, with the same adjustments for depth-related differences in sound propagation used for 2 GI guns in earlier applications. Similarly, the factors for single airguns are the same as those for a single GI gun in earlier applications. Thus, the 190 and 180 dB radii in shallow water are assumed to be 1500 m and 2400 m, respectively, for the two G. guns (LGL Ltd. 2005a,b). The corresponding radii for the single G. gun in shallow water are estimated to be 213 m and 385 m, respectively. In practice, none of the G. gun operations during the *Healy* cruise were in water <100 m deep, so these shallow-water estimates were not actually applied as safety or disturbance radii.

- Empirical measurements were not conducted for ***intermediate depths*** (100–1000 m). On the expectation that results will be intermediate between those from shallow and deep water, a 1.5× correction factor was applied to the estimates provided by the model for deep-water situations (Table 3.1). This is the same factor that has been applied to the model estimates during L-DEO seismic operations in intermediate-depth water from 2003 through early 2005. The assumed 190 and 180 dB radii in intermediate-depth water are 150 m and 500 m, respectively, for the 2 G. gun system.

- The empirical data indicated that, for ***deep water*** (>1000 m), the L-DEO model tends to overestimate the received sound levels at a given distance (Tolstoy et al. 2004a,b). However, to be precautionary pending acquisition of additional empirical data, the safety radii used during G. gun operations in deep water during the 2005 Arctic Ocean survey were the values predicted by L-DEO's modeling of those energy sources (Table 3.1; Figure C.1).

The radius at which received levels diminish to 160 dB re 1 μPa (rms) is considered by NMFS to be a possible criterion of behavioral disturbance fro cetaceans. The data on which this 160 dB criterion is based pertain to baleen whales, and many of the odontocetes (e.g., delphinids) do not appear to be as responsive to seismic sounds as are baleen whales (Richardson et al. 1995; Gordon et al. 2004). In this report, the numbers of all species exposed to ≥160 dB are estimated. However, for certain taxa (e.g., delphinids, Dall's porpoises, pinnipeds), the 170 dB radius is considered as an alternative and more realistic estimate of the outer bounds of the area within which animals are likely to be disturbed significantly. For those taxa, the numbers exposed to ≥170 dB are also estimated.

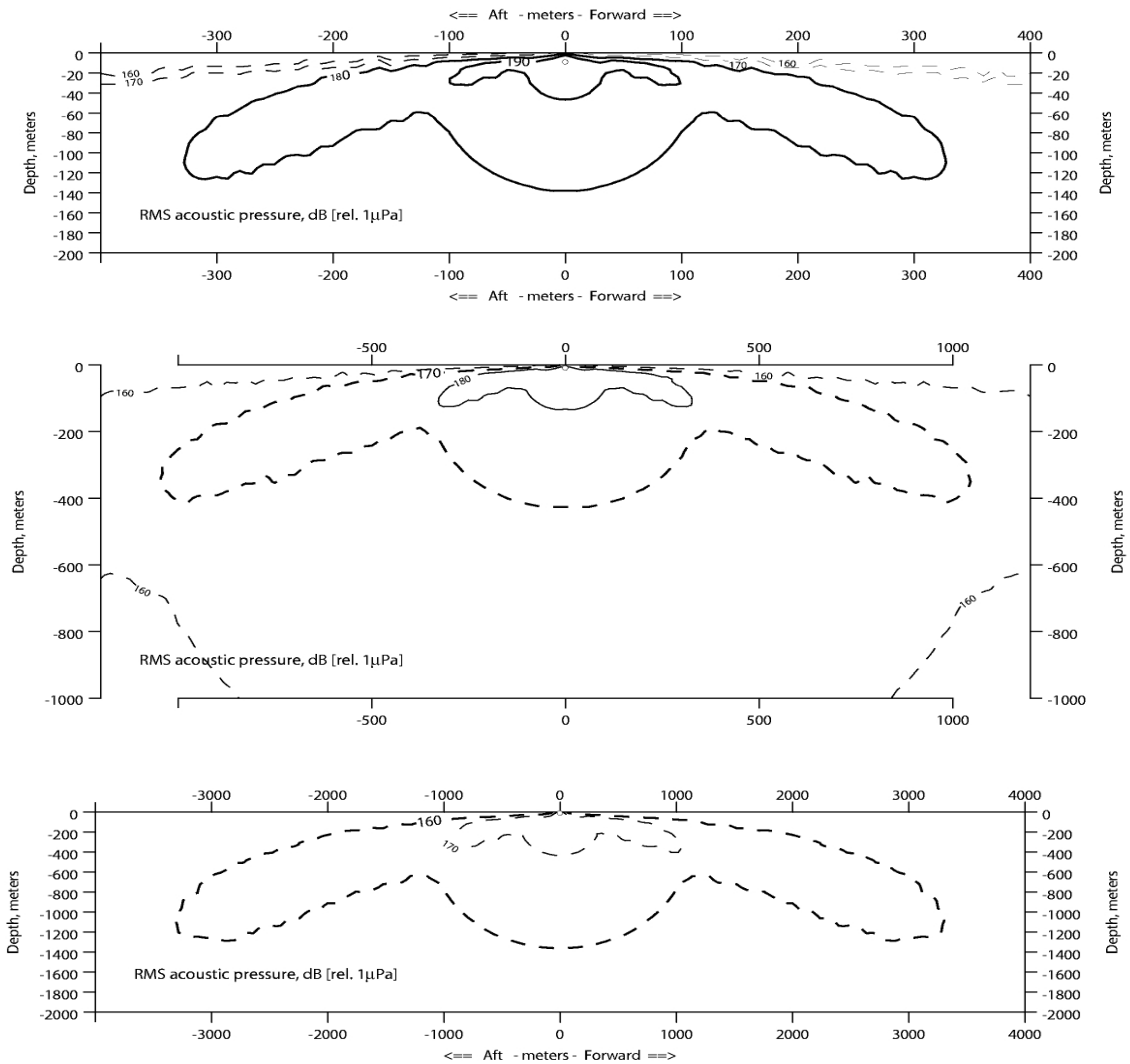

FIGURE C.1. Modeled received sound levels from the two 250 in^3 G. guns that were used during the UAF survey across the Arctic Ocean during 2005, assuming an operating depth of 9 m. The three graphs depict the same model output plotted for different maximum ranges and depths. The model does not allow for bottom interactions, so is most directly applicable to deep-water situations. Model results are provided by the Lamont-Doherty Earth Observatory of Columbia University.

APPENDIX D: DESCRIPTION OF USCG CUTTER *HEALY* AND EQUIPMENT USED DURING THE PROJECT

This appendix provides a detailed description of the standard equipment used during this and previous L-DEO seismic studies aboard the USCG cutter *Healy.*

USCG Cutter Healy *Vessel Specifications*

UAF used the USCG cutter *Healy* for the seismic study to tow the airguns and hydrophone streamer. The *Healy* was self-contained, with the crew living aboard the vessel. The *Healy* has a length of 128 m, a beam of 25 m, and a full load draft of 8.9 m (Fig. 2). The *Healy* is a USCG icebreaker, capable of traveling at 5.6 km/h (3 knots) through 1.4 m of ice. A "Central Power Plant", four Sultzer 12Z AU40S diesel generators, provides electric power for propulsion and ship's services through a 60 Hz, 3-phase common bus distribution system. Propulsion power is provided by two electric AC Synchronous, 11.2 MW drive motors, fed from the common bus through a Cycloconverter system. They, that turn two fixed-pitch, four-bladed propellers. The operation speed during seismic acquisition was, on average, ~7.4 km/h (4 knots). When not towing seismic survey gear or breaking ice, the *Healy* cruises at 22 km/h (12 knots) and has a maximum speed of 31.5 km/h (17 knots). She has a normal operating range of about 29,650 km (16,000 n. mi.) at 23.2 km/hr (12.5 knots).

Other details of the *Healy* include the following:

Owner:	USCG
Operator:	USCG
Flag:	United States of America
Date Built:	15 November 1997
Gross Tonnage:	16,000 LT
Bathymetric Survey Systems:	SeaBeam 2112 Bottom Mapping Sonar; Odec Bathy 2000; Knudsen 320 B/R Sub-bottom Profilers
Compressors for Airguns:	Portable University ob Bergen Junker compressors; capacity of 10 liters/min at 140 bar
Accommodation Capacity:	138 including ~50 scientists

The *Healy* served as a platform from which vessel-based MMOs watched for marine mammals. The flying bridge and bridge were the best available vantage points on the ship and afforded good visibility for the observers (Fig. D.1). However, visibility immediately astern of the *Healy* from the flying bridge and bridge was restricted because of intervening superstructures (Figs. D.3, D.4). The Aloft Conn offered an unobstructed view for the observers, but was only available for a limited amount of time while the ship was not underway through ice.

FIGURE D.1. The source vessel, the USCG cutter Healy, showing the locations of the flying bridge and bridge from which visual observations were made by the marine mammal observers.

Bathymetric Sonar and Sub-bottom Profilers

Along with the airgun operations, six additional acoustic systems operated during the cruise. A 12-kHz SeaBeam multibeam bathymetric (MBB) sonar and a 3.5-kHz sub-bottom profiler operated throughout most of the cruise to map the bathymetry and sub-bottom conditions, as necessary to meet the geophysical science objectives. During seismic operations, these sources typically operated simultaneously with the airgun array. An Acoustic Doppler Current Profiler operated constantly as an additional depth sounder, especially when the *Healy* was operating in shallow areas.

Multi-beam Echosounder (SeaBeam 2112)

A SeaBeam 2112 multi-beam 12 kHz bathymetric sonar system was used on the *Healy*, with a source output of 237 dB re 1 μPa at one meter. The transmit frequency was a very narrow band, less than 200 Hz, and centered at 12 kHz. Pulse lengths ranged from less than one millisecond to 12 ms. The transmit interval ranged from 1.5 s to 20 s, depending on the water depth, and was longer in deeper water. The SeaBeam 2112 system consisted of a set of underhull projectors and hydrophones. The transmitted beam was narrow (~2°) in the fore-aft direction but broad (~132°) in the cross-track direction. The system used the signals from an array of receiving hydrophones oriented perpendicular to the array of source transducers, and calculated bathymetric data (sea floor depth and some indications about the character of the seafloor) with an effective two-degree by two-degree foot print on the seafloor. The SeaBeam 2112 system on the *Healy* produced a useable swath width of slightly more than 2 times the water depth. This was narrower than normal because of the ice-protection features incorporated into the system on the *Healy*.

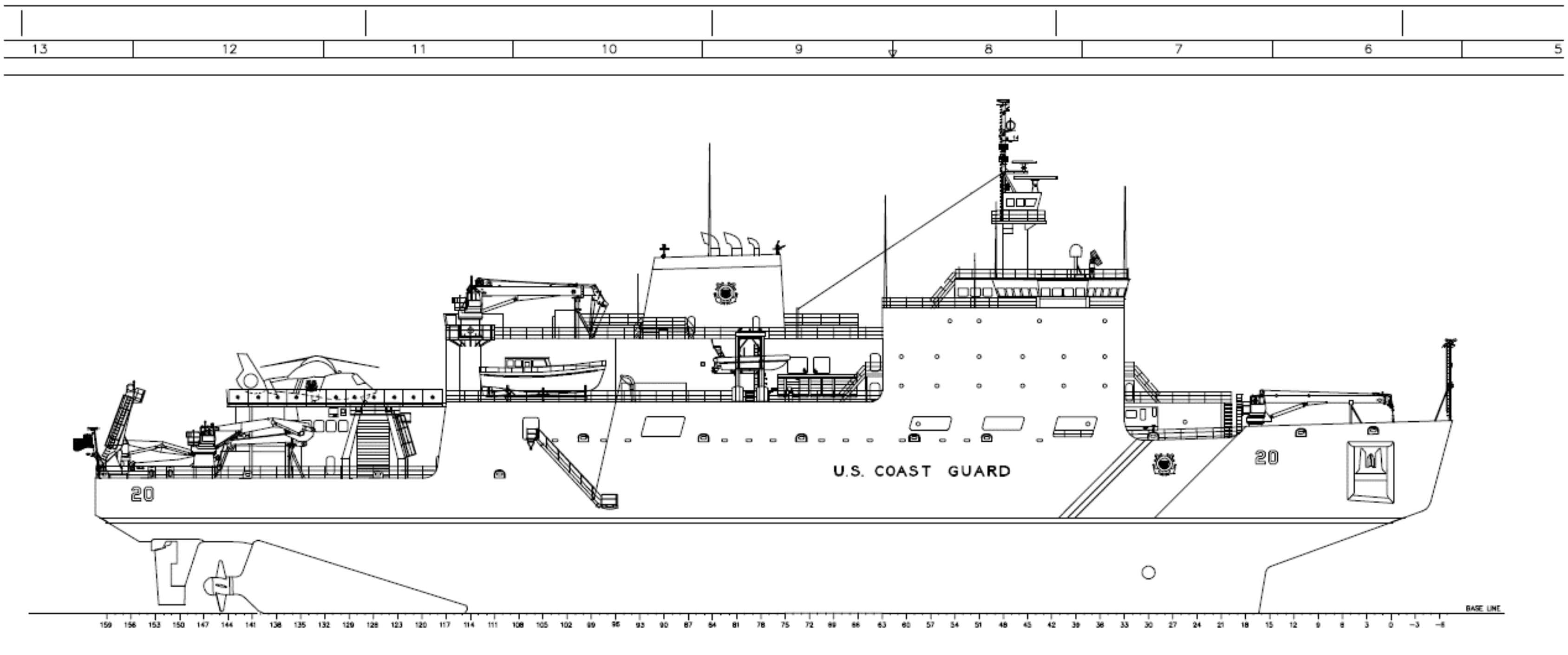

FIGURE D.2. Schematic starboard profile of the USCG cutter *Healy*.

FIGURE D.3. A view looking toward the stern from the starboard side of the flying bridge of the *Healy*, showing the ship structures that partially block the view to the stern.

FIGURE D.4. A view looking toward the stern from the port side of the bridge of the *Healy*, showing the ship structures that partially block the view to the stern.

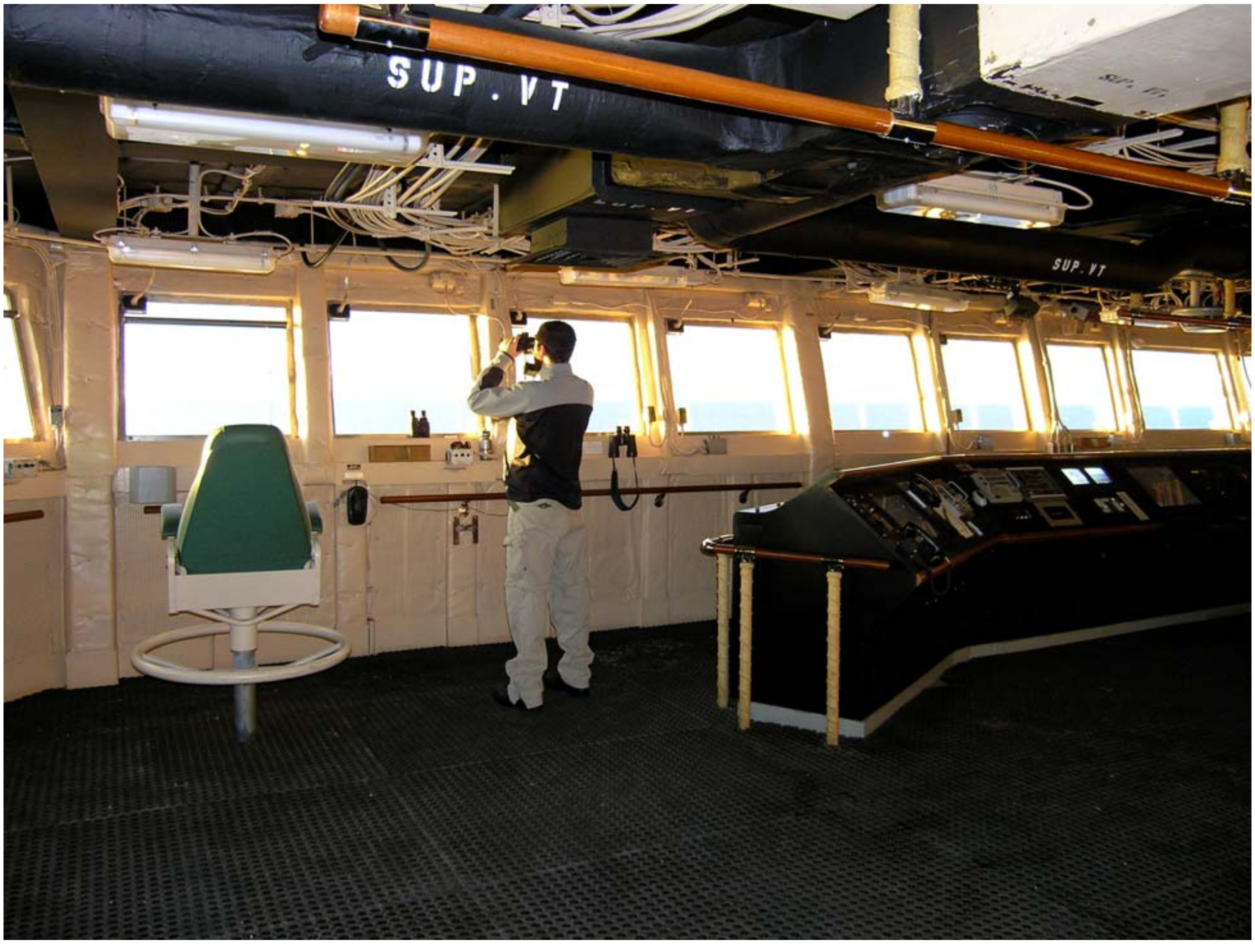

FIGURE D.5. A view of the bridge of the *Healy* showing the visual observer station.

Sub-bottom Profiler (Knudsen 320BR)

The Knudsen 320BR sub-bottom profiler provided information on sedimentary layering below the bottom, depending on bottom type and slope. It was operated with the multi-beam bathymetric sonar system that simultaneously mapped the bottom topography. During normal operation, the operator adjusted the transmit level for optimum penetration into the seafloor. The energy from the sub-bottom profiler was directed downward from the transducer array mounted in the hull of the vessel. It was a dual–frequency system with operating frequencies of 3.5 and 12 kHz. Maximum output power at 3.5 kHz was 10 kW and at 12 kHz was 2 kW. Pulse lengths up to 24 ms and bandwidths to 5 kHz were available. Pulse intervals were typically 1/2 s to about 8 s depending upon water depth. The repetition rate was range-dependent with a maximum 1% duty cycle. The Knudsen 320BR was the primary unit used for seafloor sub-bottom mapping and the Bathy 2000 (see below) was used as back-up.

There was a single 12 kHz transducer plus one 3.5 kHz, low frequency (sub-bottom) transducer array, consisting of 16 elements in a 4 × 4 array. This was used for either the Knudsen 320BR or the ODEC Bathy 2000 (see below). The beamwidth propagated by the transducers was the same for both sonar units. The 3.5 kHz transducer (TR109) emitted a conical beam with a width of 26° and the 12 kHz transducer (TC-12/34) emitted a conical beam with a width of 30°.

Sub-bottom Profiler (ODEC Bathy 2000)

The Ocean Data Equipment Corporation (ODEC) Bathy 2000 provided information on sedimentary layering down to between 20 and 70 m below the bottom, depending on bottom type and slope. The ODEC system had a maximum 7 kW transmitting capacity into the underhull array. Pulse duration ranged from 0.5 to 25 milliseconds and the interval between pulses can range between 0.25 s and 10 s depending upon water depth. The swept (chirp) frequency ranged from 2.75 kHz to 6 kHz. See above for beamwidth information.

Acoustic Doppler Current Profiler (150 kHz)

The Acoustic Doppler Current Profiler (ADCP™) operated at 150 kHz and had a minimum ping rate of 0.65 ms. There were four beam sectors and each beamwidth was 3°. The pointing angle for each beam was 30° off from vertical with one each to port, starboard, forward and aft. The four beams did not overlap. The 150 kHz Broad Band ADCP™'s maximum depth range was 300 m. The ADCP™ also served as a depth sounder in shallow water.

Acoustic Doppler Current Profiler (R D Instruments Ocean Surveyor 75)

The Ocean Surveyor 75 was an ADCP™ operating at a frequency of 75 kHz, producing a ping every 1.4 s. The system was a four-beam phased array with a beam angle of 30°. Each beam had a width of 4° and there was no overlap. Maximum output power was 1 kW with a maximum depth range of 700 m.

APPENDIX E:
Details Of Monitoring, Mitigation, and Analysis Methods

This appendix provides details on the standard visual and acoustic monitoring methods and data analysis techniques implemented for this project and previous seismic studies.

Four marine mammal observers (MMOs) were aboard the *Healy* throughout the cruise. Three MMOs were biologists experienced in marine mammal identification and observation methods. Those three individuals had served as MMOs during previous NSF-sponsored seismic programs conducted under IHAs issued by NMFS. Résumés detailing their qualifications were provided to NMFS in the past. The fourth MMO was an Inupiat with decades of experience living and hunting in the Arctic.

All MMOs participated in a review meeting before the start of the study, designed to familiarize them with the operational procedures and conditions for the cruise, reporting protocols, and IHA stipulations. In addition, implementation of the IHA requirements was explained to the Operations Manager, Lead Marine Science Technicians, Head Airgun Operator and Chief Science Party PIs aboard the vessel during a meeting prior to seismic operations. MMO duties included

- watching for and identifying marine mammals, and recording their numbers, distances and behavior;
- noting possible reactions of marine mammals to the seismic operations;
- initiating mitigation measures when appropriate; and
- reporting the results.

Visual Monitoring Methods

Visual watches took place in the seismic survey area and during transits to and from the study area. In addition to conducting watches during all seismic operations, MMOs also conducted daytime watches on a part-time basis when the source vessel was underway but the airguns were not firing. This included ***(1)*** periods during transit to and from the seismic survey area, ***(2)*** a short "pre-seismic period" while equipment was being deployed, ***(3)*** periods when the seismic source stopped firing while equipment was being repaired or coring was to take place, and ***(4)*** a short "post-seismic" period.

Visual observations were generally made from the *Healy's* bridge or flying bridge (Fig. D.1), the most suitable vantage points available on the *Healy*. For a brief period before entering heavy ice, the MMOs were allowed access to the Aloft Conn (Fig. D.1), which offered the highest vantage point on the vessel. The observer's eye level was ~21.2 m above sea level on the *Healy's* bridge and 24 m and 29.4 m on the flying bridge and Aloft Conn, respectively. Both the bridge and flying bridge afforded a view of ~270º centered on the front of the *Healy*, with obstructions to the stern (Figs. D.3, D.4). When two or more observers were standing watch, one stationed on the port and one on the starboard side of the vessel, the partial obstruction was reduced to some extent. The Aloft Conn provided a 360º view, but even from there, the area ~150 m aft of the stern (within which the G. guns were located) was not visible due to the height of the stern. Other locations toward the stern of the ship were available to MMOs, including the helicopter shack just above the flight deck, and the flight deck. However, from those locations, ~100 m of the sea surface directly off the stern was also not visible.

Watches were conducted throughout all periods of seismic surveys (all in daylight). Darkness was first encountered on 23 Sept., and the only seismic surveys thereafter were in daylight. From that date, daytime watches were conducted from dawn until dusk. Each MMO watched for at least 9 or 10 h per day during full-operation days. Visual watches aboard the *Healy* were usually conducted in 1–3 h shifts with 1–3 h breaks. At least 9 hrs were scheduled off watch for sleep. MMO(s) scanned around the vessel, alternating between unaided eyes and 7×50 Fujinon binoculars. Occasionally scans were also made using the 25×150 Big-eye binoculars when MMOs were observing from the flying bridge, to detect animals and to identify species or group size during sightings. Both the Fujinon and Big-eye binoculars were equipped with reticles on the ocular lens to measure depression angles relative to the horizon, an indicator of distance. During the day, at least one and (if possible) two MMOs were on duty. Two observers were on watch during 69% of the watches encompassing the 30-min period just before seismic operations began and during the ensuing ramp ups. (At times it was not feasible for two observers to be on duty during ramp ups because of the 24-hour watch schedule.) During the trans-Arctic Ocean survey, no nighttime watches occurred because there were no seismic operations during darkness; indeed, there were no dark periods until the last few days of the project.

The *Healy* is a participant in NMFS' Platforms of Opportunity program, and her crew regularly records marine mammal sightings and reports them to NMFS. When MMO(s) were not on active duty, the *Healy* bridge personnel watched for marine mammals during their regular watches. The bridge crew had been given instructions on how to fill out specific marine mammal sighting forms to collect pertinent information on sightings when MMOs were not on active duty. The *Healy* crew would have been relied upon for collecting marine mammal sighting data at night (except before and during ramp-ups) if any seismic operations had been conducted during nighttime. In addition to the several marine mammal sources and identification guides available on the bridge, the crew was provided with a copy of the observer instruction manual. Bridge personnel also looked for marine mammals during the day, when MMO(s) were on duty.

While on watch, visual observers kept systematic written records of the vessel's position and activity, and environmental conditions. Codes that were used for this information are shown in Table E.1. Watch data were entered manually onto a datasheet every ~30 min, as activities allowed. Additional data were recorded when marine mammals were observed. For all records, the date and time (in GMT), vessel position (latitude, longitude), and environmental conditions were recorded. Environmental conditions also were recorded whenever they changed and with each sighting record. Standardized codes were used for the records, and written comments were usually added as well.

For each sighting, the following information was recorded: species, number of individuals seen, direction of movement relative to the vessel, vessel position and activity, sighting cue, behavior when first sighted, behavior after initial sighting, heading (relative to vessel), bearing (relative to vessel), distance, behavioral pace, species identification reliability, and environmental conditions. Codes that were used to record this information during the cruise are shown in Table E.1. Distances to groups were estimated from the MMO's location (bridge, flying bridge, Aloft Conn) rather than from the nominal center of the seismic source. The distance from the sighting to the airguns was calculated during analyses. However, for sightings near or within the safety radius in effect at the time, the distance from the sighting to the nearest airgun was estimated and recorded for the purposes of implementing power downs or shut downs. The bearing from the observation vessel to the nearest member of the group was estimated using positions on a clock face, with the bow of the vessel taken to be 12 o'clock and the stern at 6 o'clock.

Operational activities that were recorded by MMOs included the number of airguns in use, total volume of the airguns in use, and type of vessel/seismic activity. The position of the vessel was automatically logged every 60 seconds by the *Healy's* navigation system. Those data were copied from the electronic database into the MMO database, using recorded time as the identifier. Specific information regarding the seismic activities (number of guns and volume) was collected from a log that the gunners maintained. Inter-ship communication

TABLE E.1. Summary of data codes used during the Aug.– Sept. 2005 trans-Arctic seismic survey.

WS	Watch Start
WE	Watch End

OBS. LOCATION

BR	Bridge
FB	Flying bridge
AC	Aloft conn
AFC	Aft conn

LINE

Enter Line ID or leave blank

SEISMIC ACTIVITY

RU	Ramping up
LS	Line Shooting
SH	Shooting Between/Off.Lines
ST	Seismic Testing
PD	Power Down
SZ	Safety Zone Shut-Down
SD	Shut-Down
DP	Deploying equipment
RC	Recovering equipment
OT	Other (comment and describe)

 # GUNS

Enter Number of Operating Airguns,

ARRAY VOLUME

Enter operating volume,

(BEAUFORT) SEA STATE

See Beaufort Scale sheet.

LIGHT OR DARK

L	Light (day)
D	Darkness

GLARE AMOUNT

NO	None
LI	Little
MO	Moderate
SE	Severe

POSITION

Clock Position, or

99	Variable (vessel turning)

WATER DEPTH

In meters

MARINE MAMMAL SPECIES

Baleen Whales

BHW	Bowhead Whale
BLW	Blue Whale
FW	Fin Whale
GW	Gray Whale
SW	Sei Whale
HW	Humpback Whale
MW	Minke Whale
NARW	North Atlantic Right Whale
UMW	Unidentified Mysticete Whale
UW	Unidentified Whale

Large Toothed Whales

BW	Beluga Whale
KW	Killer Whale
NW	Narwhal
NBW	Northern Bottlenose Whale
SPW	Sperm Whale
LFPW	Long-finned Pilot Whale
UTW	Unidentified Tooth Whale

Dolphins

AWS	Atlantic White-Sided Dolphin
AWBD	Atlantic White-Beaked Dolphin
UD	Unidentified Dolphin

Porpoises

HP	Harbor Porpoise
DP	Dall's Porpoise

Pinnipeds

BS	Bearded Seal
HBS	Harbor Seal
HDS	Hooded Seal
HPS	Harp Seal
RS	Ringed Seal
SS	Spotted Seal
US	Unidentified Seal
UP	Unidentified Pinniped
AWA	Atlantic Walrus
PWA	Pacific Walrus

TURTLE SPECIES

LB	Leatherback Turtle

MOVEMENT

PE	Across Bow
ST	Swim Toward
SA	Swim Away
FL	Flee
SP	Swim Parallel
MI	Mill
HO	Hauled Out
WT	Walk Toward
NO	No movement
DE	Dead
UN	Unknown

INDIVIDUAL BEHAVIOR

MA	Mating
SI	Sink
FD	Front Dive
TH	Thrash Dive
DI	Dive
LO	Look
LG	Logging
SW	Swim
BR	Breach
LT	Lobtail
SH	Spyhop
FS	Flipper Slap
FE	Feeding
FL	Fleeing
BL	Blow
BO	Bow Riding
MI	Milling
ST	Swimming Toward
PO	Porpoising
RA	Rafting
WR	Wake Riding
WA	Walk
AG	Approaching Guns
OT	Other (describe)
NO	None (sign seen only)
UN	Unknown

GROUP BEHAVIOR (BEHAVIORAL STATES)

TR	Travel
SA	Surface Active
ST	Surface Active-Travel
MI	Milling
FG	Feeding
RE	Resting
OT	Other (describe)
UN	Unknown

 # RETICLES or ESTIMATE

(of Initial Distance, etc.; Indicate Big-eye or Fujinons or clinometer in comments)

0 to 16	Number of reticles
E	Estimate, by eye
CLINO #	reading of degrees through clinometer

SIGHTING CUE

BO	Body
HE	Head
SP	Splash
FL	Flukes
DO	Dorsal Fin
BL	Blow
RI	Ripple
BI	Birds

IDENTIFICATION RELIABILITY

MA	Maybe
PR	Probably
PO	Positive

BEHAVIOR PACE

SE	Sedate
MO	Moderate
VI	Vigorous

ACOUSTIC MONITORING

BL	Begin listening
L	Listening
EL	End listening

among the geophysicists, seismic technicians, *Healy* crew Marine Science Technicians and the MMOs was conducted via radio or telephone and used to alert the MMOs to any changes in operations.

All data were initially recorded on custom paper datasheets in the field and were entered into a Microsoft Excel® database at the end of the day. The database was constructed to prevent entry of out-of-range values and codes. Data entries were checked manually by comparing listings of the computerized data with the original handwritten datasheets, both in the field and upon later analyses. Data collected by the MMOs were also checked against the navigation and shot logs collected automatically by the vessel's computers, and against the geologists' electronic project log.

Acoustic Monitoring Methods

Sonobuoys deployed by the geophysicists were monitored on a systematic, part-time basis by the MMOs for about 33% of the time while they were conducting visual watches. Details are given in Chapter 3, "Acoustic Monitoring Methods".

Mitigation

Ramp-up, power-down, and shut-down procedures, which are described briefly in Chapter 3, are described in detail below. These were the primary forms of mitigation implemented during seismic operations

Ramp-up Procedures

A "ramp-up" procedure was implemented at the commencement of seismic operations and anytime after the guns had been shut down for a specified duration. Under normal operating conditions (average vessel speed ~4 kt), a ramp up of the 2 G. guns was conducted after a shut down longer than 5 min.

The IHA required that, during the daytime, the entire safety radius be visible (i.e., not obscured by fog, etc.), and monitored for 30 min prior to and during ramp up, and that the ramp up could only commence if no marine mammals were detected within the safety radius during this period. Throughout the ramp ups, the safety zone was considered to be that appropriate for the guns operating at full volume in the water depth occurring at the time. Ramp up was to be suspended if marine mammals were detected within the safety radius. Ramp up of the 2 G. guns was not permitted at night given the provisions of the IHA, i.e., no powering up unless the entire safety zone was visible. However, during this high-latitude cruise, there was no night (darkness) until late in the cruise, and there were no G. gun operations at night.

Power-down and Shut-down Procedures

Airgun operations were immediately shut down or powered down to half volume, i.e., from 2×250 in^3 to 2×125 in^3, when one or more marine mammals were detected within, or judged about to enter, the appropriate safety radius (see Table 3.1 in Chapter 3).

The power-down procedure was to be accomplished within several seconds (or a "one-shot" period) of the determination that a marine mammal was within or about to enter the safety radius. Full airgun operations were not to resume until the animal was outside the safety radius, or had not been seen for a specified amount of time (15 min for dolphins and pinnipeds, and 30 min for whales). Once the safety radius was judged to be clear of marine mammals based on those criteria, the MMOs advised the airgun operators and full-volume operations resumed.

In contrast to a power down, a shut down refers to the complete cessation of firing by all airguns. If a marine mammal was seen within the designated safety radius applicable to powered-down airguns during either full seismic operations or during a power down, a complete shut down was necessary. The shut-down procedure was to be accomplished within several seconds (or a "one-shot" period) of the determination that a marine mammal was within or about to enter the safety radius. Seismic operations were not to resume until the animal was outside the safety radius, or had not been seen for a specified amount of time (15 min for dolphins and 30 min for whales). Once the safety radius was judged to be clear of marine mammals based on those criteria, the MMO advised the gun operators that seismic surveys could re-commence, and ramp up was initiated.

The MMOs were stationed on the flying bridge or bridge about 100 m ahead of the closest airgun in the array; the closest airgun was located ~5 m aft of the *Healy's* stern. The decision to initiate a power down or shut down was based on the distance of the marine mammal from the observers rather than from the airguns, unless the animals were sighted closer to the airguns than to the observers. This was another precautionary measure, given that most sightings were ahead of the vessel.

Analyses

This section describes the analyses of the marine mammal sightings and survey effort as documented during the cruise. It also describes the methods used to calculate densities and estimate the number of marine mammals potentially exposed to seismic sounds associated with the seismic survey. Sightings of marine mammals hauled out on the ice were included with sightings of marine mammals in the water for the density estimates. To calculate exposures, all the animals calculated in the density estimates were assumed to be in the water. Only marine mammals observed in the water were included in the direct estimates of animals exposed to seismic pulses. The analysis categories that were used were identified in Chapter 3. The primary analysis categories used to assess potential effects of seismic sounds on marine mammals were the "seismic" (airguns operating with shots at <3 min spacing) and "non-seismic" categories (periods before seismic started or >2 h after airguns were turned off). The analyses excluded the "post-seismic" period 3 min to 2 h after the airguns were turned off. The justification for the selection of these criteria is based on the size of the array in use and is provided below. These criteria were discussed in earlier L-DEO cruise reports to NMFS (see Haley and Koski 2004; Smultea et al. 2004, 2005; MacLean and Koski 2005; Holst et al. 2005a,b):

- The period up to 3 min after the last seismic shot is ~9× the normal shot interval. Mammal distribution and behavior during that short period are assumed to be similar to those while seismic surveying is ongoing.
- It is likely that any marine mammals near the vessel between 3 min and 30 min after the cessation of seismic activities would have been "recently exposed" (i.e., within the past 30 min) to sounds from the seismic survey. During at least a part of that period, the distribution and perhaps behavior of the marine mammals may still be influenced by the (previous) sounds.
- For some unknown part of the period from 30 min to 2 h post-seismic, it is possible that the distribution of the animals near the ship, and perhaps the behavior of some of those animals, would still be at least slightly affected by the (previous) seismic sounds.
- By 2 h after the cessation of seismic operations, the distribution and behavior of marine mammals would be expected to be indistinguishable from "normal" because of (a) waning of responses to past seismic activity, (b) re-distribution of mobile animals, and (c) movement of the ship and thus the MMOs. Given those considerations, plus the limited observed responses of most marine mammals to seismic surveys (e.g., Stone 2003; Smultea et al. 2004; Haley and Koski 2004; MacLean and Koski 2005; Holst et al. 2005a,b), it is unlikely that the distribution or behavior of marine mammals near the vessel >2 h post-seismic would be appreciably different from "normal" even if they had been exposed to seismic sounds earlier. Therefore, we consider animals seen >2 h after cessation of seismic operations to be unaffected by the (previous) seismic sounds.

As summarized in Chapter 3, marine mammal density was one of the parameters examined to assess differences in the distribution of marine mammals relative to the seismic vessel between seismic and non-seismic periods. Line-transect procedures for vessel-based surveys were followed. To allow for animals missed during daylight, we corrected our visual observations for missed cetaceans by using approximate correction factors derived from previous studies. (It was not practical to derive study-specific correction factors during a survey of this type and duration.) It is recognized that the most appropriate correction factors will depend on specific observation procedures during different studies, ship speed, and other variables. Thus, use of correction factors derived from other studies is not ideal, but it provides more realistic estimates of numbers present than could be obtained without the use of correction factors at all.

The formulas for calculating densities using this procedure were briefly described in Chapter 3 and are described in more detail below. As standard for line-transect estimation procedures, densities were corrected for the following two parameters before they were further analyzed:

- *g*(0), a measure of detection bias. This factor allows for the fact that less than 100% of the animals present along a trackline are detected.
- *f*(0), the reduced probability of detecting an animal with increasing distance from a trackline.

The *g*(0) and *f*(0) factors used in this study were taken from results of previous work, not from observations made during this study. Sighting rates during the present study were either too small or, at most, marginal to provide meaningful data on *f*(0) based on group size. Further, this type of project cannot provide data on *g*(0). Estimates of these correction factors were derived from Martin and Smith (1992), Koski et al. (1998), Harwood et al. (1996), Barlow (1999), Thomas et al. (2002), and Heide-Jørgensen et al., for corresponding species and Bf. Marine mammal sightings were subjected to species-specific truncation criteria obtained from the above studies.

Number of Exposures — Estimates of the numbers of potential *exposures* of marine mammals to sound levels ≥160 dB re 1 µPa (rms) were calculated by multiplying the total area of water ensonified to that degree by the density of marine mammals estimated by line transect methods. The density estimates include all marine mammals, in the water or on ice. The exposure estimates assume that the numbers of animals estimated from those densities are all in the water. The area of water ensonified was calculated using MapInfo Geographic Information System (GIS) software to create a "buffer" that extended on both sides of the vessel's trackline to the predicted 160-dB radius. Because the 160-dB radius varied with the water depth, the width of the buffer also varied with water depth (Table E.2). The buffer included areas that were exposed to airgun sounds ≥160 dB one or more times (as a result of crossing tracklines or tracklines that were close enough for their 160 dB zones to overlap). Areas of water ensonified on more than one occasion, due to overlapping tracklines, were repeatedly counted in the area calculation as many times as they were ensonified. "Corrected" densities of marine mammals were estimated as described in the above section.

Estimates of the numbers of potential *exposures* of marine mammals to sound levels ≥160 dB re 1 µPa (rms) were calculated by multiplying the following three values:

- number of kilometers of seismic survey,
- width around trackline ensonified to ≥160 dB re 1 µPa (rms) including *repeated counts* of areas ensonified on more than on occasion, and
- observed densities of marine mammals – "corrected" as summarized above

This value provides a maximum estimate of the number of exposures to sound levels ≥160 dB re 1 µPa (rms) if marine mammals did not show avoidance reactions.

TABLE E.2. The areas (km^2) potentially ensonified to various levels by the 2 G. guns operating in two water depth strata within the study area (intermediate depths, 100–1000 m, and deep, >1000 m) during seismic periods of the Arctic Ocean cruise, 10 Aug–26 Sep. 2005. ***(A)*** Maximum area ensonified, with overlapping areas counted multiple times. ***(B)*** Total area ensonified at least once, with overlapping areas counted only once.

	Water Depth 100 - 1000 m				Water Depth >1000 m				
Area (km^2)	160 dB	170 dB	180 dB	190 dB	160 dB	170 dB	180 dB	190 dB	Total
A. Including Overlap Area	6448.2	1682.3	475.9	137.4	13689.1	4056.8	1209.6	367.2	28066.6
B. Excluding Overlap Area	6093.5	1628.3	467.8	135.5	12009.3	3936.6	1186.0	355.4	25812.5

Number of Individuals Exposed — The method described above likely overestimates the number of different *individual* marine mammals exposed to airgun sounds at received levels ≥160 dB. To provide an estimate of individuals exposed, the same calculation described above was performed, except that areas ensonified to ≥160 dB on more than one occasion, due to overlapping tracklines, were counted only once. In this project, involving mainly a linear trackline, the amount of overlap was slight, but for consistency with earlier projects, the following procedure was applied nonetheless.

Estimates of the potential number of *individual* marine mammals exposed to sound levels ≥160 dB re 1 μPa (rms) were calculated by multiplying the following three values:

- number of kilometers of seismic survey,
- width around trackline ensonified to ≥160 dB re 1 μPa (rms) including *only one count* of areas ensonified on more than on occasion, and
- observed densities of marine mammals – "corrected" as summarized above

The area of water considered ensonified in this calculation is therefore smaller than in the first calculation. During this cruise, the estimated number of individuals exposed is similar to the estimated number of exposure incidents because seismic lines were not closely spaced and therefore little overlap of ensonified areas occurred (see Fig. 4.1). The calculated number of different individual marine mammals exposed to ≥160 dB re 1 μPa (rms) is considered a minimum estimate because it does not account for the movement of marine mammals during the course of the study.

The process outlined above was repeated for pinnipeds and delphinids, assuming that for those animals, the estimated 170 dB radius (see Table 3.1) was a more realistic estimate of the maximum distance at which significant disturbance would occur. That radius was used to estimate both the number of exposures and the number of individuals exposed to seismic sounds with received levels ≥170 dB re 1 μPa (rms). The process was also repeated for all cetacean species based on the estimated 180-db radius. That was done to estimate the numbers of animals that would have been subjected to sounds with received levels ≥180 dB re 1 μPa (rms) if they had not altered their course to avoid those sound levels (or the ship).

APPENDIX F:
BACKGROUND ON MARINE MAMMALS IN THE TRANS-ARCTIC OCEAN PROJECT REGION

TABLE F.1. The habitat, abundance, and conservation status of marine mammals inhabiting the trans-Arctic Ocean survey area.

Species	Habitat	Abundance (Beaufort Sea)	Abundance (Svalbard/ Norwegian Sea/NE Atlantic)	ESA[1]	IUCN[2]	CITES[3]
Odontocetes Sperm whale (*Physeter macrocephalus*)	Pelagic, deep seas	0	7785[4] 5200[5] 1542[6]	Endangered	VU	I
Beluga whale (*Delphinapterus leucas*)	Offshore, Coastal, Ice edges	50,000[7] 39,257[8]	300-3000[9]	Not listed	VU	II
Narwhal (*Monodon monoceros*)	Offshore, Ice edge	60,000[10]	100[43]	Not listed	DD	II
North Atlantic bottlenose whale (*Hyperoodon ampullatus*)	Continental shelf, submarine canyons	0	3142[12] 287[13] 40,000[14]	Not listed	LR-cd	I
Killer whale (*Orcinus orca*)	Widely distributed	Rare	6618[6] 3100[15]	Not listed	LR-cd	II
Long-finned pilot whale (*Globicephala melas*)	Mostly pelagic	0	778,000[16]	Not listed	-	II
Atlantic white-sided dolphin (*Lagenorhynchus acutus*)	Shelf and slope waters	0	>100,000[17]	Not listed	-	II
Atlantic white-beaked dolphin (*Lagenorhynchus albirostris*)	Continental shelf	0	132,000[18]	Not listed	-	II
Harbor Porpoise (*Phocoena phocoena*)	Coastal, inland waters	Extralimital	350,000[19]	Not listed	VU	II
Mysticetes Bowhead whale (*Balaena mysticetus*)	Pack ice & coastal	10,470[20]	Tens[5] 10[43]	Endangered	LR-cd	I
North Atlantic right whale (*Eubalaena glacialis*)	Coastal and shelf waters	0	250-300[21]	Endangered	EN	I
Gray whale (*Eschrichtius robustus*) (eastern Pacific population)	Coastal, lagoons	488[22] 17,500[44]	0	Not listed	LR-cd	I
Humpback whale (*Megaptera novaeangliae*)	Mainly near-shore and banks	0	700[5] 1100[23] 1816[6]	Endangered	VU	I
Minke whale (*Balaenoptera acutorostrata*)	Shelf, coastal	0	41,131[6]	Not listed	LR-cd	I
Sei whale (*Balaenoptera borealis*)	Primarily offshore, pelagic	0	1000[24]	Endangered	EN	I

Species	Habitat	Abundance (Beaufort Sea)	Abundance (Svalbard/ Norwegian Sea/NE Atlantic)	ESA[1]	IUCN[2]	CITES[3]
Fin whale (*Balaenoptera physalus*)	Slope, mostly pelagic	0	1906[5] 7167[6]	Endangered	EN	I
Blue whale (*Balaenoptera musculus*)	Pelagic and coastal	0	1000[5] 442[6]	Endangered	EN	I
Pinnipeds Walrus (*Odobenus rosmarus*)	Coastal, pack ice, ice	188,316[25]	15,000[26] <2000[27] 500-1000[28]	Not listed	-	II
Bearded seal (*Erignathus barbatus*)	Pack ice	300,000-450,000[29] 4863[30]	300,000[41]	Not listed	-	-
Harbor seal (*Phoca vitulina*)	Coastal	N.A.	3800[31] 500-600[42]	Not listed	-	-
Spotted seal (*Phoca largha*)	Pack ice	1000[32]	0	Not listed	-	-
Ringed seal (*Pusa hispida*)	Landfast & pack ice	Up to 3.6 million [33] 245,048[34] 326,500[35]	1.3 million [36]	Not listed	-	-
Hooded seal (*Cystophora cristata*)	Pack ice	0	102,000[37]	Not listed	-	-
Harp seal (*Pagophilus groenlandicus*)	Pack ice	0	361,000[37]	Not listed	-	-
Ursids Polar bear (*Ursus maritimus*)	Coastal, ice	1500-1800[38] 15,000[39]	2000[40]	Not listed	LR-cd	-

[1] Endangered Species Act.

[2] IUCN Red List of Threatened Species (2002). Codes for IUCN classifications: CR = Critically Endangered; EN = Endangered; VU = Vulnerable; LR = Lower Risk (-cd = Conservation Dependent; -nt = Near Threatened; -lc = Least Concern); DD = Data Deficient.

[3] Convention on International Trade in Endangered Species of Wild Fauna and Flora (UNEP-WCMC 2004).

[4] Abundance estimate for the Icelandic, Faroe Islands and Northeast Atlantic populations from Whitehead (2002).

[5] Abundance estimate for the Norwegian Sea from Christensen et al. (1992).

[6] Abundance estimate for Icelandic, Faroese, and adjacent waters from Gunnlaugsson and Sigurjónsson (1990).

[7] Total Western Alaska population, including Beaufort Sea animals that occur there in winter (Small and DeMaster 1995).

[8] Beaufort Sea population (IWC 2000).

[9] Svalbard population (Bjørge et al. 1991; IWC 2000).

[10] DFO 2004. This is mainly the population in Baffin Bay and the Canadian arctic archipelago; very few of these enter the Beaufort Sea.

[11] West Greenland population, World Council of Whalers.

[12] Icelandic population (Reyes 1991).

[13] Faroese population (Reyes 1991).

[14] Eastern North Atlantic population (NAMMCO Annual Report 1995).

[15] Norwegian and Barents seas (Reyes 1991).

[16] Abundance estimate for the eastern North Atlantic from Buckland et al. (1993).

[17] Atlantic population (Cipriano 2002).

[18] Abundance estimate for all delphinids (consisting of about 90% white-beaked dolphins) in the Barents, eastern Norwegian, and North Sea (north of 56ºN) from Øien (1996 *in* Reeves et al. 1999).

[19] North Sea population (Hammond et al. 2001; 2002).

[20] Abundance of bowhead whales surveyed near Barrow, as of 2001 (George et al. 2004).
[21] North Atlantic population (DFO 2004).
[22] Southern Chukchi Sea and northern Bering Sea (Clark and Moore 2002).
[23] Abundance estimate for the Northeast Atlantic from Øien (1990).
[24] Abundance estimate for Icelandic, Faroese and adjacent waters from Cattanach et al. (1993).
[25] Pacific walrus population (USFWS 2000).
[26] Estimate for Atlantic walrus (Pagophilus.org).
[27] Svalbard-Franz Joseph Land population estimate (NAMMCO 1995).
[28] Eastern Greenland population estimate (NAMMCO 1995).
[29] Alaska population (USDI/MMS 1996).
[30] Eastern Chukchi Sea population (NMML, unpublished data).
[31] Abundance estimate for Norway from Reijnders et al. (1997 *in* Thompson et al. 1998).
[32] Alaska Beaufort Sea population (USDI, MMS 1996).
[33] Alaska estimate (Frost et al. 1988 *in* Angliss and Lodge 2004).
[34] Bering/Chukchi Sea population (Bengston et al. 2000).
[35] Alaskan Beaufort Sea population estimate (Amstrup 1995).
[36] Eastern Canada and western Greenland estimate (NAMMCO n.d.).
[37] Abundance estimate for the Greenland Sea (NAMMCO 2001).
[38] Amstrup (1995).
[39] NWT Wildlife and Fisheries, http://www.nwtwildlife.rwed.gov.nt.ca/Publications/speciesatriskweb/polarbear.htm
[40] Polar bear status report for Svalbard, Polar Bears International, http://www.polarbearsinternational.org/facts.php
[41] Population estimate for the North Atlantic (Burns 1981).
[42] Svalbard population estimate (Henriksen et al. 1997).
[43] Svalbard population (CAFF n.d.).
[44] North Pacific gray whale population (Rugh 2003 *in* Keller and Gerber 2005).

APPENDIX G:
VISUAL AND ACOUSTIC EFFORT AND DETECTIONS

TABLE G.1. All and useable[a] visual observation effort from the *Healy* within the trans-Arctic Ocean study area, 10 August–26 September 2005, in ***(A)*** hours, and ***(B)*** kilometers, subdivided by water depth and airgun status. Ramp-up effort is included in the "Seismic" category.

	All Effort		Useable[a] Effort	
Water Depth (m)	100-1000	>1000	100-1000	>1000
(A) Effort in h				
Non-Seismic	53	702	52	639
Post Seismic	25	70	N/A	N/A
Seismic	60	234	42	164
Total	**138**	**1006**	**94**	**803**
(B) Effort in km				
Non-Seismic	251	4398	243	4023
Post Seismic	103	357	N/A	N/A
Seismic	449	1824	309	1288
Total	**803**	**6579**	**552**	**5311**

[a] Includes only useable visual effort as defined in *Acronyms and Abbreviations.*

TABLE G.2. All and useable[a] visual observation effort from the *Healy* within the Arctic Ocean study area, 10 August–26 September 2005, in ***(A)*** hours, and ***(B)*** kilometers, subdivided by Beaufort Wind Force (Bf) and airgun status. Ramp-up effort is included in the "Seismic" category.

	All Effort				Useable[a] Effort			
Beaufort Wind Force	0	1	2	*Total*	0	1	2	*Total*
(A) Effort in h								
Non-Seismic	280	13	1	*294*	217	13	1	*231*
Post Seismic[b]	66	8	2	*76*	N/A	N/A	N/A	N/A
Seismic	240	51	4	*295*	163	39	3	*205*
Total	**586**	**72**	**7**	**665**	**380**	**52**	**4**	**436**
(B) Effort in km								
Non-Seismic	1965	136	22	*2123*	1583	136	22	*1741*
Post Seismic[b]	323	40	10	*373*	N/A	N/A	N/A	N/A
Seismic	1843	398	32	*2273*	1266	307	24	*1597*
Total	**4130**	**574**	**64**	**4768**	**2849**	**443**	**46**	**3338**

[a] Includes only useable visual effort as defined in *Acronyms and Abbreviations.*

TABLE G.3. Sightings of marine mammals made from the USCG cutter *Healy* along the Arctic Ocean trackline and during transits, 5 Aug. – 30 Sept. 2005. All marine mammal observations were visual; none were detected acoustically.

Species	Useable (Y) or Non-Useable (N)[a]	Grp Size	Day in 2005	Time (GMT)	Latitude (°N)	Longitude (-=°W +=°E)	Initial Sighting Distance (m) from observer	CPA[b] Distance from G. Guns (m)	Initial Move-ment[c]	Initial Behav.[d]	Bf[e]	Water Depth (m)	Vessel Activ.[f]	G. guns Vol. (in^3)[g]	Mitig. (SZ, PD, None)[h]
Dall's Porpoise	Y	8	5-Aug	20:21:03	54.2261	-166.5177	1099	1099	ST	ST	2	>1000	OT	0	None
Humpback Whale	Y	2	5-Aug	20:25:04	54.2431	-166.5230	3001	3001	SA	SW	2	>1000	OT	0	None
Dall's Porpoise	Y	3	5-Aug	20:42:39	54.3174	-166.5451	1375	1462	SA	SW	2	100-1000	OT	0	None
Humpback Whale	Y	1	5-Aug	20:50:38	54.3508	-166.5352	350	438	UN	SW	2	100-1000	OT	0	None
Unidentified Whale	Y	1	5-Aug	23:58:00	55.1369	-166.6203	5015	5065	SA	MI	2	<100	OT	0	None
Unidentified Whale	Y	1	6-Aug	00:13:00	55.2015	-166.6304	4010	4060	SP	BL	2	<100	OT	0	None
Dall's Porpoise	Y	3	6-Aug	00:15:20	55.2114	-166.6311	75	124	SA	ST	2	<100	OT	0	None
Unidentified Whale	N	1	8-Aug	14:45:45	67.6715	-168.6211	1240	1327	SP	SW	6	<100	OT	0	None
Pacific Walrus	N	1	8-Aug	23:50:20	69.9703	-167.2420	80	180	DE	NO	6	<100	OT	0	None
Ringed Seal	N	1	9-Aug	05:51:51	71.4875	-165.5608	20	118	NO	LO	6	<100	OT	0	None
Pacific Walrus	N	1	9-Aug	11:21:20	72.8266	-164.3278	15	113	ST	DI	3	<100	OT	0	None
Pacific Walrus	Y	6	9-Aug	11:40:25	72.8974	-164.2553	500	600	MI	LO	1	<100	OT	0	None
Unidentified Seal	Y	1	9-Aug	17:58:33	73.7454	-162.6907	650	737	SA	SW	0	100-1000	OT	0	None
Unidentified Seal	N	1	9-Aug	19:04:03	73.7913	-162.4421	1219	1306	HO	LO	0	100-1000	OT	0	None
Unidentified Seal	N	1	9-Aug	19:52:10	73.8224	-162.2194	9260	9310	NO	LG	0	100-1000	OT	0	None
Unidentified Seal	Y	1	9-Aug	20:48:08	73.8771	-161.9173	3262	3361	NO	RE	0	100-1000	OT	0	None
Ringed Seal	Y	1	9-Aug	22:22:29	73.9770	-161.4510	600	687	SP	SW	0	100-1000	OT	0	None
Ringed Seal	Y	1	9-Aug	22:31:58	73.9911	-161.4081	550	638	SA	SW	0	100-1000	OT	0	None
Polar Bear	Y	1	10-Aug	07:37:22	74.3950	-160.2429	1084	1137	HO	RE	0	100-1000	LS	500	None
Ringed Seal	Y	1	10-Aug	19:52:20	74.6615	-159.5069	45	104	SA	TH	0	>1000	LS	500	None
Unidentified Seal	Y	1	12-Aug	01:58:50	76.3940	-157.2407	400	451	SA	DI	0	>1000	LS	500	None
Ringed Seal	Y	1	12-Aug	03:55:46	76.5244	-157.1171	80	173	SA	FD	0	>1000	LS	500	None
Ringed Seal	Y	1	12-Aug	15:25:20	77.1957	-157.0700	45	92	MI	SW	0	100-1000	LS	250	PD
Bearded Seal	Y	1	14-Aug	14:18:33	78.0981	-151.8519	160	225	MI	SW	0	>1000	LS	500	None

TABLE G.3 (continued).

Species	Useable (Y) or Non-Useable (N)[a]	Grp Size	Day in 2005	Time (GMT)	Latitude (°N)	Longitude (-=°W +=°E)	Initial Sighting Distance (m) from observer	CPA[b] Distance from G. Guns (m)	Initial Move-ment[c]	Initial Behav.[d]	Bf[e]	Water Depth (m)	Vessel Activ.[f]	G. guns Vol. (in^3)[g]	Mitig. (SZ, PD, None)[h]
Ringed Seal	Y	1	14-Aug	19:57:28	78.1923	-153.5327	202	266	SA	SW	0	>1000	LS	500	None
Unidentified Seal	Y	1	16-Aug	00:13:14	78.1981	-160.3675	200	264	PE	FD	1	>1000	LS	500	None
Ringed Seal	Y	1	16-Aug	00:20:34	78.2023	-160.4029	300	360	SA	LO	1	>1000	LS	500	None
Unidentified Seal	Y	1	16-Aug	00:25:15	78.2053	-160.4294	150	242	SA	LO	1	>1000	LS	500	None
Unidentified Seal	Y	1	16-Aug	15:16:04	78.3020	-163.3786	92	185	MI	LO	0	100-1000	OT	0	None
Bearded Seal	N	1	17-Aug	06:46:25	78.2786	-167.3760	40	136	SP	SW	1	100-1000	LS	250	PD
Ringed Seal	N	1	17-Aug	16:50:31	78.2851	-170.4581	250	340	SA	SW	0	>1000	LS	500	None
Bearded Seal	Y	1	18-Aug	01:28:20	78.2922	-173.2017	579	635	SP	LO	0	>1000	LS	500	None
Ringed Seal	N	1	18-Aug	10:38:20	78.2993	-176.2834	85	179	NO	LO	0	>1000	LS	500	None
Ringed Seal	Y	1	18-Aug	12:16:12	78.2948	-176.8314	134	234	SA	SW	0	100-1000	LS	500	None
Unidentified Seal	N	1	18-Aug	13:05:47	78.2827	-177.1118	200	300	DE	NO	0	100-1000	LS	500	None
Unidentified Seal	Y	1	18-Aug	19:55:53	78.0019	-176.9047	210	274	SA	SW	0	>1000	DP	0	None
Ringed Seal	Y	1	18-Aug	20:24:04	78.0278	-176.9091	868	956	HO	LO	0	>1000	LS	500	None
Unidentified Seal	Y	1	18-Aug	21:54:40	78.1386	-176.9460	242	304	SP	SW	0	100-1000	LS	500	None
Unidentified Seal	Y	1	19-Aug	00:49:30	78.3597	-176.8492	303	403	SA	SW	0	100-1000	LS	500	None
Ringed Seal	Y	1	19-Aug	01:18:58	78.3954	-176.8181	201	265	ST	SW	0	100-1000	LS	500	None
Ringed Seal	Y	1	19-Aug	14:23:32	78.2857	-177.2068	200	148	PE	SW	0	100-1000	LS	500	SZ
Ringed Seal	Y	1	19-Aug	14:26:10	78.2852	-177.2202	100	173	MI	SW	0	100-1000	OT	0	None
Ringed Seal	Y	1	19-Aug	14:58:02	78.2921	-177.3706	242	332	MI	LO	0	>1000	LS	500	None
Polar Bear	Y	3	19-Aug	16:19:47	78.3241	-177.8153	80	128	HO	WT	0	>1000	LS	500	None
Unidentified Seal	Y	1	19-Aug	17:30:33	78.3471	-178.2368	1085	1173	HO	LO	0	>1000	LS	500	None
Ringed Seal	Y	1	19-Aug	17:48:37	78.3533	-178.3420	992	1079	HO	LO	0	>1000	LS	500	None
Unidentified Seal	Y	1	19-Aug	18:29:14	78.3673	-178.5886	320	409	ST	SW	0	>1000	LS	500	None

TABLE G.3 (continued).

Species	Useable (Y) or Non-Useable (N)[a]	Grp Size	Day in 2005	Time (GMT)	Latitude (°N)	Longitude (-=°W +=°E)	Initial Sighting Distance (m) from observer	CPA[b] Distance from G. Guns (m)	Initial Move-ment[c]	Initial Behav.[d]	Bf[e]	Water Depth (m)	Vessel Activ.[f]	G. guns Vol. (in^3)[g]	Mitig. (SZ, PD, None)[h]
Ringed Seal	Y	1	19-Aug	19:22:00	78.4035	-178.6053	350	449	MI	LO	0	>1000	LS	500	None
Polar Bear	N	1	19-Aug	22:03:54	78.5416	-177.9139	230	329	HO	WT	0	>1000	LS	500	None
Unidentified Seal	Y	1	20-Aug	04:19:49	78.8550	-176.3294	600	655	HO	LO	0	>1000	LS	500	None
Unidentified Seal	Y	1	20-Aug	04:22:57	78.8606	-176.2877	500	589	HO	LO	0	>1000	LS	500	None
Unidentified Seal	N	1	20-Aug	05:43:17	78.9246	-175.9711	699	786	ST	SW	0	>1000	LS	500	None
Unidentified Seal	Y	1	20-Aug	06:03:20	78.9415	-175.8897	195	285	PE	SW	0	>1000	LS	500	None
Unidentified Seal	Y	1	20-Aug	09:51:32	79.0945	-175.1267	348	448	SA	LO	0	>1000	LS	500	None
Unidentified Seal	Y	1	20-Aug	12:08:52	79.2161	-174.4936	80	180	SA	SW	0	>1000	LS	500	None
Unidentified Seal	Y	1	20-Aug	16:18:02	79.4144	-173.4231	650	738	HO	LO	0	>1000	LS	500	None
Ringed Seal	N	1	21-Aug	18:34:56	79.9129	-170.5033	543	631	HO	RE	0	>1000	OT	0	None
Ringed Seal	Y	1	21-Aug	20:49:35	79.9641	-170.3123	200	291	PE	LO	0	>1000	LS	500	None
Ringed Seal	Y	1	21-Aug	20:52:02	79.9646	-170.3299	300	360	NO	LO	0	>1000	LS	500	None
Unidentified Seal	Y	1	21-Aug	22:36:35	79.9942	-171.0223	250	339	PE	SW	0	>1000	LS	500	None
Unidentified Seal	Y	1	22-Aug	01:47:17	80.0461	-172.3465	202	302	MI	LO	0	>1000	LS	500	None
Unidentified Seal	Y	1	22-Aug	02:00:51	80.0492	-172.4445	1448	1500	HO	RE	0	>1000	LS	500	None
Ringed Seal	Y	1	22-Aug	02:39:18	80.0594	-172.7197	300	360	HO	LO	0	>1000	LS	500	None
Unidentified Seal	Y	1	22-Aug	03:40:12	80.0746	-173.1472	650	738	HO	LO	0	>1000	LS	500	None
Ringed Seal	Y	1	22-Aug	04:09:36	80.0811	-173.3630	579	679	HO	RE	0	>1000	LS	500	None
Unidentified Seal	Y	1	22-Aug	05:24:18	80.1045	-173.8702	427	200	NO	LO	0	>1000	LS	500	None
Ringed Seal	Y	1	22-Aug	06:01:24	80.1466	-173.9849	128	219	NO	LO	0	>1000	LS	500	None
Ringed Seal	Y	1	23-Aug	12:05:06	81.4051	-177.4005	134	203	SP	LO	0	>1000	LS	500	None
Unidentified Seal	Y	1	28-Aug	20:01:00	84.2950	-160.1371	350	439	PE	SW	0	>1000	OT	0	None
Unidentified Seal	Y	1	28-Aug	20:26:19	84.2802	-159.7510	250	312	UN	SW	0	>1000	OT	0	None
Unidentified Seal	Y	1	28-Aug	20:40:14	84.2722	-159.5590	75	175	SA	SW	0	>1000	OT	0	None

TABLE G.3 (continued).

Species	Useable (Y) or Non-Useable (N)[a]	Grp Size	Day in 2005	Time (GMT)	Latitude (°N)	Longitude (-=°W +=°E)	Initial Sighting Distance (m) from observer	CPA[b] Distance from G. Guns (m)	Initial Move-ment[c]	Initial Behav.[d]	Bf[e]	Water Depth (m)	Vessel Activ.[f]	G. guns Vol. (in^3)[g]	Mitig. (SZ, PD, None)[h]
Ringed Seal	Y	1	29-Aug	00:20:34	84.2011	-156.9368	250	340	SA	LO	0	>1000	RU	250	None
Bearded Seal	Y	1	1-Sep	21:17:57	84.5343	-153.0802	250	340	SA	DI	0	>1000	LS	500	None
Ringed Seal	Y	1	2-Sep	02:59:23	84.8674	-154.0748	80	174	MI	LO	0	>1000	LS	500	None
Bearded Seal	Y	1	2-Sep	19:05:17	85.5056	-154.9527	200	300	PE	SW	0	>1000	LS	500	None
Ringed Seal	Y	1	4-Sep	04:13:30	86.2227	172.9179	80	180	PE	LO	0	>1000	OT	0	None
Unidentified Seal	Y	1	5-Sep	10:57:20	86.6179	166.7740	242	342	SA	SW	0	>1000	LS	500	None
Ringed Seal	Y	1	5-Sep	18:53:10	86.5925	158.2159	175	183	MI	LO	0	>1000	LS	500	None
Ringed Seal	Y	1	8-Sep	11:43:05	88.2922	155.1223	200	291	SA	SW	0	>1000	RU	250	None
Ringed Seal	Y	1	8-Sep	11:48:21	88.2867	155.0408	151	243	SA	LO	0	>1000	RC	0	None
Ringed Seal	Y	1	8-Sep	13:15:50	88.291	152.2787	230	210	SA	SW	0	>1000	LS	500	None
Ringed Seal	Y	1	8-Sep	18:29:04	88.5061	153.9466	134	234	PE	DI	0	>1000	LS	500	None
Unidentified Seal	Y	1	8-Sep	20:44:50	88.462	149.0017	100	193	PE	LO	0	>1000	LS	500	None
Unidentified Seal	Y	1	10-Sep	04:05:15	88.6340	161.9106	180	271	HO	LO	1	>1000	LS	500	None
Ringed Seal	Y	1	10-Sep	06:30:20	88.6905	168.8917	303	393	MI	LO	1	>1000	LS	500	None
Ringed Seal	N	1	11-Sep	05:57:13	88.9624	178.1078	151	251	SA	SW	1	>1000	DP	0	None
Unidentified Seal	Y	1	14-Sep	10:18:52	89.1394	73.4398	80	174	PE	TH	0	>1000	OT	0	None
Polar Bear	N	3	17-Sep	20:29:30	87.2031	57.8071	202	302	HO	WA	0	>1000	OT	0	None
Ringed Seal	Y	1	17-Sep	22:21:20	87.137	58.043	200	300	PE	SW	0	>1000	OT	0	None
Ringed Seal	Y	2	18-Sep	21:52:51	86.6335	54.8255	120	212	MI	SW	0	>1000	OT	0	None
Unidentified Seal	Y	1	19-Sep	01:38:06	86.5644	53.2356	20	120	SA	TH	0	>1000	OT	0	None
Unidentified Seal	Y	1	20-Sep	14:36:36	85.7954	47.2370	40	140	SA	DI	0	>1000	OT	0	None
Ringed seal	Y	1	21-Sep	13:48:46	85.2017	44.6434	1085	250	HO	NO	0	>1000	OT	0	None
Polar Bear	Y	1	23-Sep	07:10:08	82.6767	42.9822	3000	3087	HO	WA	0	>1000	OT	0	None
Polar Bear	Y	1	23-Sep	11:00:37	82.247	39.4553	1500	1587	HO	SI	0	>1000	OT	0	None
Polar Bear	Y	1	23-Sep	12:03:26	82.1713	37.9790	1500	200	HO	FE	0	>1000	OT	0	None
Bearded Seal	Y	1	23-Sep	12:29:21	82.1376	37.4266	1740	1840	HO	RE	0	>1000	OT	0	None

TABLE G.3 (continued).

Species	Useable (Y) or Non-Useable (N)[a]	Grp Size	Day in 2005	Time (GMT)	Latitude (°N)	Longitude (-=°W +=°E)	Initial Sighting Distance (m) from observer	CPA[b] Distance from G. Guns (m)	Initial Movement[c]	Initial Behav.[d]	Bf[e]	Water Depth (m)	Vessel Activ.[f]	G. guns Vol. (in^3)[g]	Mitig. (SZ, PD, None)[h]
Bearded Seal	Y	1	23-Sep	14:40:01	82.0425	35.5628	2937	3024	HO	RE	0	>1000	OT	0	None
Polar Bear	Y	1	23-Sep	14:46:10	82.0352	35.4513	1053	965	HO	LO	0	>1000	OT	0	None
Polar Bear	Y	1	23-Sep	14:49:51	82.0308	35.3878	1173	1085	HO	FE	0	>1000	OT	0	None
Bearded Seal	Y	2	23-Sep	15:05:26	82.0247	35.1717	489	400	HO	FL	0	>1000	OT	0	None
Polar Bear	Y	1	23-Sep	15:13:41	82.0150	35.0207	3024	2937	HO	WT	0	>1000	OT	0	None
Polar Bear	Y	1	23-Sep	15:15:18	82.0140	34.9904	3037	2937	HO	WA	0	>1000	OT	0	None
Unidentified Seal	Y	1	23-Sep	15:32:50	81.9963	34.7352	2270	2183	HO	RE	0	>1000	OT	0	None
Unidentified Seal	Y	1	24-Sep	06:59:29	81.3412	23.2581	250	350	PE	LO	1	100-1000	OT	0	None
Polar Bear	Y	1	24-Sep	07:33:38	81.3290	22.9879	4000	4087	HO	LO	1	100-1000	OT	0	None
Unidentified Seal	Y	1	24-Sep	11:40:22	81.4527	21.2322	80	180	MI	LO	0	>1000	OT	0	None
Unidentified Seal	Y	1	24-Sep	12:13:20	81.4802	20.8249	25	125	SA	SW	0	>1000	OT	0	None
Polar Bear	Y	1	25-Sep	05:09:02	81.5250	16.1587	100	193	HO	LO	0	>1000	OT	0	None
Unidentified Seal	Y	1	25-Sep	11:21:50	81.2082	15.6601	303	403	SA	SW	0	>1000	OT	0	None
Polar Bear	Y	1	25-Sep	11:52:44	81.1717	15.4816	405	494	HO	LO	0	>1000	OT	0	None
Polar Bear	Y	1	26-Sep	10:53:24	80.4746	7.4530	789	877	HO	WA	0	100-1000	OT	0	None
Polar Bear	Y	1	26-Sep	10:56:34	80.4746	7.4440	2183	2270	HO	WT	0	100-1000	OT	0	None
Polar Bear	N	1	26-Sep	11:19:53	80.4736	7.4327	4552	4639	HO	WA	0	100-1000	OT	0	None
Polar Bear	N	1	26-Sep	11:31:32	80.4731	7.4312	2906	2993	HO	WA	0	100-1000	OT	0	None
Polar Bear	Y	3	26-Sep	16:00:34	80.4631	6.9046	800	888	HO	MI	0	100-1000	OT	0	None
Polar Bear	Y	1	26-Sep	16:51:09	80.4310	6.7864	1448	1500	HO	WA	0	100-1000	OT	0	None
Polar Bear	Y	1	26-Sep	17:13:35	80.4169	6.7394	1200	1287	HO	LO	0	100-1000	OT	0	None
Unidentified Dolphin	Y	1	28-Sep	09:51:36	73.3669	14.6244	110	203	SA	SW	4	100-1000	OT	0	None
Unidentified Dolphin	Y	2	29-Sep	08:37:10	70.8184	18.6496	100	172	SP	SW	2	100-1000	OT	0	None
Minke whale	Y	1	29-Sep	08:57:30	70.8214	18.9071	1392	1444	SP	BL	3	100-1000	OT	0	None

TABLE G.3 (continued).

a Usable or Non-useable sightings. Y=Visual sightings made during daylight periods both within the seismic survey area and during transit to and from that area, N=periods 3 min to 2 h after guns were turned off (post-seismic), poor visibility conditions (visibility <2 km), and periods with Beaufort Wind Force >5. Also excluded were periods when >1 radian of severe glare occurred between 90º left and 90º right of the bow.

b CPA is the distance at the closest observed point of approach to the nearest airgun. This is not necessarily the distance at which the individual or group was initially seen nor the closest it was observed to the vessel.

c The initial movement of the individual or group relative to the vessel. DE=dead, HO=hauled out, MI=milling, PE=swimming perpendicular to ship or across bow, SA=swimming away, SP=swimming parallel, ST=swimming toward, UN=unknown, NO = none.

d The initial behavior observed; BL=blowing, DI=diving, FD=front dive, FE=feeding, FL=fleeing, LO=looking, MI=milling, NO=no movement, RE=resting, SI=sink, ST=swimming toward, SW=swimming, TH=thrash dive, TR=traveling, UN=unknown, WA=walk, WT=walk toward.

e   Beaufort Wind Force scale (which is not the same as the “Sea State” scale).

f   Activity of the vessel at the time of the sighting; LS=operating G. gun on a seismic survey line and collecting geophysical data, OT=other (a period of no seismic activity), DP=deploying seismic gear, RC= recovering seismic gear,).

g The GI guns operated at a volume of either 250 in3 or 500 in3.

h Mitigating measures. SZ= safety zone shut down, PD=power down, None.

TABLE G.4. Total number of groups (individuals in parentheses) of marine mammals observed from the *Healy* by species, seismic activity, and transit periods during the trans-Arctic Ocean seismic cruise, 5 Aug. – 30 Sept. 2005. See Table 4.1 for the total number of useable[a] sightings (a subtotal of the numbers shown here).

	Within Study Area			Transit Periods			
Species	**Non-Seismic**	**90 s- 2 h Post-Seismic**	**Seismic**	**Transit from Dutch Harbor**	**Transit to Tromsø Norwary**	**Total Group Sightings**	**Total Indiv.**
Dall's Porpoise	0	0	0	3 (14)	0	3	14
Unidentified dolphin	0	0	0	0	2 (3)	2	3
Humpback Whale	0	0	0	2 (3)	0	2	3
Minke Whale	0	0	0	0	1 (1)	1	1
Unidentified Whale	0	0	0	3 (3)	0	3	3
Bearded Seal	2 (2)	0	5 (5)	0	0	7	7
Ringed Seal	4 (4)	2 (2)	29 (29)	3 (3)	0	38	38
Unidentified Seal	13 (13)	0	23 (23)	4 (4)	0	40	40
Pacific Walrus	0	0	0	3 (8)	0	3	8
Polar Bear	12 (15)	2 (2)	5 (7)	0	3 (5)	22	29
Total	**31 (34)**	**4 (4)**	**62 (64)**	**18 (35)**	**6 (9)**	**121**	**146**

[a] Defined in *Acronyms and Abbreviations.*

TABLE G.5. All and useable[a] acoustic monitoring effort conducted from the *Healy* within the Arctic Ocean study area, 10 Aug. – 26 Sept. 2005, in ***(A)*** hours, and ***(B)*** kilometers, subdivided by airgun status. Ramp-up effort is included in the "Seismic" category.

	All Effort		Useable[a] Effort	
Water Depth (m)	100-1000	>1000	100-1000	>1000
(A) Effort in h				
Seismic	17	71	12	51
Post Seismic	2	8	0	0
Total	**19**	**79**	**12**	**51**
(B) Effort in km				
Seismic	131	560	92	408
Post Seismic	6	40	0	0
Total	**137**	**600**	**92**	**408**

[a] Includes acoustic monitoring effort that occurred coincident with useable visual effort as defined in *Acronyms and Abbreviations.*

APPENDIX H:
SIGHTINGS WITH POWER DOWNS AND SHUT DOWNS DURING THE ARCTIC OCEAN CRUISE

A total of three power downs of the 2 G. guns were requested due to marine mammal sightings within the nominal 180 and 190 dB safety radii during the Arctic Ocean cruise. All three sightings were of individual pinnipeds. Each sighting occurred in intermediate water depths (100-1000 m), where the defined safety radius for pinnipeds was 150 m (Table 3.1). One bearded seal and one ringed seal may have been exposed to sound pressure levels ≥190 dB; a single ringed seal was likely exposed to sound pressure levels ≥190 dB, as follows:

- A single ringed seal was observed 12 Aug. at 15:20 GMT while the 2 G. guns were operating in 500 m deep water. The seal was milling in a small area on the port side of the ship, ~45 m from the observer, or ~145 m from the active guns. The fantail and Aft Conn were radioed to power down, but neither copied the call. The seal did not move as the Healy proceeded along her track. The seal dove in a calm manner several seconds after the initial sighting when it was perpendicular to the observer and estimated to be ~92 m from the G. guns. The ringed seal was not observed after that dive. After several unsuccessful attempts by the marine mammal observers to contact the gunners, the bridge relayed the call for a power down. The gunners did not hear the call and did not implement the power down until ~2 minutes after the seal was observed diving within the 150 m safety radius. The ringed seal was seen ~92 m from the operating G. guns in 500 m deep water when the 190 dB safety radius was 150 m. It is ***likely*** that the ringed seal was exposed to sound levels ≥190 dB when it dove.
- On 17 Aug. at 6:46:25 GMT, an individual bearded seal was sighted in 481 m deep water while both G. guns were firing. The defined 2 G. gun safety radius for pinnipeds in intermediate water depths (100-1000 m) was 150 m. The seal was observed swimming parallel to the *Healy*, 40 m from the bridge or ~140 m from the operating airguns. A power down was immediately implemented. The seal sank straight down into the water seconds after it was first observed. The bearded seal's closest observed point of approach to the operating G. guns was ~136 m. At that distance from the G. guns, predicted sound levels are ≥190 dB only at significant depth (Fig. C.1.). It is unlikely that the seal reached that depth in the seconds prior to the power down. The bearded seal was seen within the 150 m safety radius when both G. guns were firing in intermediate water depth. It is possible, though ***unlikely***, that the seal was briefly exposed to sound levels ≥190 dB when it sank into the water.
- A single ringed seal was sighted on 19 Aug. at 14:23:32 GMT in water 860 m deep while both G. guns were operating. The seal was initially seen swimming at a moderate pace across the bow of the *Healy* at a distance of ~200 m from the bridge, or 300 m from the airguns. The individual seal looked at the ship once before it dove under the ice as the ship approached. What is believed to be the same ringed seal was seen again at 14:25:33 GMT, 109 m off the port beam of the bridge, or ~148 m from the operating G. guns. Because the seal was within the 150 m safety zone, a power down was initiated. After two unsuccessful radio calls to the gunners on the fantail, the MMO phoned the Aft Conn to relay the need for a power down to the gunners. The gunners implemented a shut down of the airguns because they misunderstood the request for a power down as a request for a shut down. The ringed seal was seen diving within the 150 m safety radius ~30 s before seismic activities were terminated in intermediate depth water. It is possible, though ***unlikely***, that the seal was briefly exposed to sound levels ≥190 dB when it dove. At its distance from the G. guns (148 m), it would have had to dive deeply and swiftly in order to reach the predicted 190 dB zone before the G. guns stopped firing. The ringed seal never showed a strong avoidance behavior. A second ringed seal was spotted at 14:26:10 GMT milling off the port bow, as close as 85 m from the vessel and ~100 m from the G. guns. Since the G. guns had already been shut down, the individual was not exposed to G. gun sounds with received levels ≥190 dB.

APPENDIX I:
MARINE MAMMAL DENSITY AND EXPOSURE ESTIMATES

TABLE I.1. Expected densities of marine mammals in offshore areas of the Beaufort and Chukchi seas **near Barrow, Alaska**. Densities are corrected for *f*(0) and *g*(0) biases. Species listed under the U.S. Endangered Species Act (ESA) as endangered are in italics.

Species	Average Density (# / km^2) [a]	Maximum Density (# / km^2)
Odontocetes		
Sperm whale	*0.0000*	*0.0000*
Ziphiidae		
Northern bottlenose whale	0.0000	0.0000
Monodontidae		
Beluga [b]	0.0034	0.0135
Narwhal [f]	0.0000	0.0001
Delphinidae		
Atlantic white-beaked dolphin	0.0000	0.0000
Atlantic white-sided dolphin	0.0000	0.0000
Killer whale	0.0000	0.0000
Long-finned pilot whale	0.0000	0.0000
Phocoenidae		
Harbor porpoise [f]	0.0000	0.0002
Mysticetes		
North Atlantic right whale	*0.0000*	*0.0000*
Bowhead whale [b]	*0.0064*	*0.0256*
Gray whale [c]	0.0045	0.0179
Humpback whale	*0.0000*	*0.0000*
Minke whale	0.0000	0.0000
Sei whale	*0.0000*	*0.0000*
Fin whale	*0.0000*	*0.0000*
Blue whale	*0.0000*	*0.0000*
Pinnipeds		
Walrus [f]	0.0003	0.0010
Bearded seal [d]	0.0128	0.0226
Harbor seal	0.0000	0.0000
Spotted seal [f]	0.0001	0.0005
Ringed seal [e]	0.2510	0.4440
Hooded seal	0.0000	0.0000
Harp seal	0.0000	0.0000
Ursids		
Polar bear [g]	0.0016	0.0040

[a] Coefficients of variation (CVs) are not given because the density estimates come from various sources with widely differing methodologies so CVs would not be comparable.

[b] Calculated from summer surveys of Moore et al. (2000) in the Alaskan Beaufort Sea; most sightings were far to the east of the proposed seismic survey. Maximum densities are assumed to be one half of the observed densities and mean densities are assumed to be 1/8th of observed densities.

[c] Calculated from summer surveys of Moore et al. (2000) in the Chukchi Sea; most sightings were far to the southwest of the proposed seismic survey or along the coast near Pt. Barrow. Maximum densities are assumed to be one half of the observed densities and mean densities are assumed to be 1/8th of observed densities.

[d] Ringed seal density ×0.051 based on the ratio of bearded-to-ringed seals in Stirling et al. (1982).

[e] Average density is the mean pack-ice density from Kingsley (1986). Maximum density is average density ×4.

[f] There are no reliable survey data for these species in the present area. As they are known to occur in the proposed seismic survey area (primarily near Barrow) we have arbitrarily inserted densities based on their relative abundance.

[g] Estimated from sightings and effort in Moulton and Williams (2003).

TABLE I.2. Expected densities of marine mammals in the polar pack ice **between Alaska and Svalbard**. Densities are corrected for *f*(0) and *g*(0) biases. Species listed under the U.S. ESA as endangered are in italics.

Species	**Average Density (# / km^2)**	**Maximum Density (# / km^2)**
Odontocetes		
Sperm whale	*0.0000*	*0.0000*
Ziphiidae		
Northern bottlenose whale	0.0000	0.0000
Monodontidae		
Beluga [b]	0.0002	0.0007
Narwhal [c]	0.0028	0.0112
Delphinidae		
Atlantic white-beaked dolphin	0.0000	0.0000
Atlantic white-sided dolphin	0.0000	0.0000
Killer whale	0.0000	0.0000
Long-finned pilot whale	0.0000	0.0000
Phocoenidae		
Harbor porpoise	0.0000	0.0000
Mysticetes		
North Atlantic right whale	*0.0000*	*0.0000*
Bowhead whale [b]	*0.0007*	*0.0026*
Gray whale	0.0000	0.0000
Humpback whale	*0.0000*	*0.0000*
Minke whale	0.0000	0.0000
Sei whale	*0.0000*	*0.0000*
Fin whale	*0.0000*	*0.0000*
Blue whale	*0.0000*	*0.0000*
Pinnipeds		
Walrus	0.0000	0.0000
Bearded seal [b]	0.0013	0.0051
Harbor seal	0.0000	0.0000
Spotted seal	0.0000	0.0000
Ringed seal [b]	0.0126	0.0444
Hooded seal	0.0000	0.0000
Harp seal	0.0000	0.0000
Ursids		
Polar bear	0.0002	0.0004

[a] Coefficients of variation (CVs) are not given because the density estimates come from various sources with widely differing methodologies so CVs would not be comparable.

[b] Density is estimated as (the density for the area north of Barrow + the density for the area north of Svalbard)/20

[c] Average density is the density in offshore Baffin Bay from Koski and Davis (1994) corrected for *g*(0) × 0.01. Maximum density is average density ×4.

TABLE I.3. Expected densities of marine mammals during surveys in the offshore pack ice **north of Svalbard**. Densities are corrected for *f*(0) and *g*(0) biases. Species listed under the U.S. ESA as endangered are in italics.

Species	Average Density (# / km^2)	Maximum Density (# / km^2)
Odontocetes		
Sperm whale [b]	*0.0005*	*0.0049*
Ziphiidae		
Northern bottlenose whale [c]	0.0001	0.0004
Monodontidae		
Beluga [d]	0.0001	0.0005
Narwhal [e]	0.0006	0.0023
Delphinidae		
Atlantic white-beaked dolphin [c]	0.0001	0.0004
Atlantic white-sided dolphin [c]	0.0001	0.0004
Killer whale [c]	0.0001	0.0004
Long-finned pilot whale [c]	0.0000	0.0001
Phocoenidae		
Harbor porpoise [c]	0.0000	0.0001
Mysticetes		
North Atlantic right whale [c]	*0.0000*	*0.0001*
Bowhead whale	*0.0001*	*0.0004*
Gray whale	0.0000	0.0000
Humpback whale [c]	*0.0001*	*0.0004*
Minke whale [c]	0.0001	0.0004
Sei whale [c]	*0.0000*	*0.0001*
Fin whale [c]	*0.0001*	*0.0004*
Blue whale [c]	*0.0001*	*0.0004*
Pinnipeds		
Walrus [c]	0.0001	0.0004
Bearded seal [f]	0.0128	0.0226
Harbor seal	0.0000	0.0000
Spotted seal	0.0000	0.0000
Ringed seal [f]	0.2510	0.4440
Hooded seal [g]	0.0043	0.0075
Harp seal [g]	0.0128	0.0226
Ursids		
Polar bear	0.0016	0.0040

[a] Coefficients of variation (CVs) are not given because the density estimates come from various sources with widely differing methodologies so CVs would not be comparable.

[b] The maximum density is the northeast Atlantic density from Whitehead (2002) and the average density is 10% of the maximum density because few sperm whales are expected to be found amidst the pack ice.

[c] These species are not expected to occur in the pack ice north of Svalbard. A nominal (low) average and maximum density are given.

[d] The population north of Svalbard is about 1/30th of the Beaufort population so the average and maximum estimates are assumed to be 1/30th of the Beaufort densities

[e] The narwhal population is about 1/5th of the beluga population so the narwhal density estimates are 1/5th of the beluga estimates.

[f] No data are available for this area; the density is assumed to be the same as in the pack ice in the Beaufort Sea.

[g] The population of harp seals is approximately the same as the population of hooded seals is approximately one third of the bearded seal population.